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Award Year 2021

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Breeding Designer Apple Rootstocks to Match Nutrient Parameters Under Organic Management

Accession No.	1027438
Project No.	NYG-632552
Agency	NIFA NY.G\
Project Type	OTHER GRANTS
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Contract / Grant No.	2021-51106-35767
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Investigator(s)	Robinson, T. L.; Fazio, GE, .

NON-TECHNICAL SUMMARY

Organic apple production in the Eastern US is small and is mostly based on existing rootstocks, which are susceptible to fire blight which creates a very high risk of infection and tree death. The incorporation of disease-resistant rootstocks would greatly reduce the risk. New resistant, dwarfing rootstocks also allow high-density orchards, which begin production in the second or third leaf can achieve 50% higher yields than traditional orchards. This project will develop and then extend to Eastern organic apple growers information on the best rootstock options for various soils and climate situations. The results of the project will be packaged into an online, smart rootstock recommendation system that will allow organic apple growers to input the specifics of their future orchard and receive a specific recommendation of the best rootstock choice considering climate, soil, cultivar and location. The project will support OREI Goal 1. Facilitating the development and improvement of organic agriculture production, breeding, and processing methods; Goal 4. Determining desirable traits for organic commodities; and Goal 6. Conducting advanced on-farm research and development that emphasizes observation of, experimentation with, and innovation for working organic farms, including research relating to production, marketing, food safety, socioeconomic conditions, and farm business management. Overall, we expect this project to lead to increased commercial organic apple production in the Eastern USA to meet the increasing demand for locally produced organic apples.

OBJECTIVES

The project will support OREI Goal 1. Facilitating the development and improvement of organic agriculture production,Goal 4. Determining desirable traits for organic commodities; and Goal 6. Conducting advanced on-farm research and development The long-term goals of this project are: Identify and deploy improved apple rootstocks with a range of vigor levels among newly released and unreleased advanced test selections from the Geneva apple rootstock breeding program for organic apple growers that will provide high productivity, high fruit quality and resistance to several important diseases and climate events affecting organic apple production. Determine rootstock effects related fruit mineral profile under organic management especially effects on nutrients that affect fruit quality and susceptibility to storage disorders. Develop and deploy an online smart rootstock recommendation system that considers the location, soil, and cultivar of the new orchard to then provide rootstock recommendations for organic apple growers.

APPROACH

We willconduct field research over three seasons in two dedicated organic apple research orchards at Cornell\'s Geneva Experiment Station and at Singer Farms in Appleton, NY. At Geneva we will conduct replicated experiments on rootstock performance, and rootstock influence on fruit quality, fruit mineral profile and fruit storage disorders on three apple cultivars (Modi, a disease resistant variety, Honeycrisp and Ruby Frost, both disease susceptible varieties).We will also establish one new experimental plot at Geneva in 2020where we will evaluate the performance of 11 new disease resistant apple rootstocks with Snapdragon variety for growth and production performance .These rootstocks will also be monitored at the DNA level to validate the effectiveness of DNA markers for improving rootstock performance under organic management. Year 1 (2021)Evaluate new rootstock in organic apple production in trial at Geneva and Singer Farms in Appleton NY. Measure fruit mineral nutrient profile of new rootstocks and correlate them with fruit size, fruit quality and fruit storage disorders especially bitter pit.Y ear 2 (2022)Conduct rootstock evaluations of new rootstocks for organic production at Geneva and Singer Farms in Appleton NY. Measure fruit mineral nutrient profile of new rootstocks and correlate them with fruit size, fruit quality and fruit storage disorders especially bitter pit. Begin the development of an online smart rootstock decision tool for organic apple production in the Eastern US. Year 3 (2023)Conduct rootstock evaluations of new rootstocks for organic production at Geneva and Singer Farms in Appleton NY. Measure fruit mineral nutrient profile of new rootstocks and correlate them with fruit size, fruit quality and fruit storage disorders especially bitter pit. Conduct a grower workshops with NOFA-NY on rootstocks and cultivars (fall). Finish the development and launch the online smart rootstock decision tool for organic apple production in the Eastern US. Compile final report. We will conduct our research in four dedicated organic apple research plots at Cornell\'s Geneva Experiment Station and one plot at Singer Farms in Appleton NY. Objective 1:We will compare the horticultural performance of new disease resistant Geneva® rootstocks on tree growth and yield in 5 field plots listed above. We will evaluate tree growth, survival, yield and fruit quality each year from 2021-2023. Tree health will be monitored throughout the trial. Dead trees and possible reason for loss will be recorded each year at the time when growth measurements are taken. The incidence of rootstock suckering will also be recorded during this study. From our field data we will develop a set of recommended rootstocks for organic growers that have sufficient growth to fill the allotted space (\~3 ft) by the end of the third year, while producing high yields in the first 5-10 years.Objective 2We will evaluate nutrient profiles in the fruit as affected by rootstock and then correlate nutrient levels to yield, fruit size, quality and fruit disorders. Ten randomly selected fruits distributed throughout the tree canopy will be harvested 120 days after bloom on three replicates of each rootstock genotype from of each of the 5 field trials mentioned above.The ten sampled fruits will be peeled (lower half of the fruit -calyx end) and the peels will be bulked into one sample per tree for analysis.Fruit peels will be oven dried, ground into powder and shipped to the Great Lakes analysis lab for mineral analysis of several macro- and micro-mineral nutrients via inductively coupled plasma optical emission spectrometry.Leaf K and Ca concentration of the fruit from one field trial (Geneva \'Modi\' experiment) will be measured with a hand held Xray nutrient analyzer instrument. Soil samples will be collected from 6 field locations from all research plots and will be analyzed for nutrients after modified Morgan extraction at Agro-One, Ithaca, NY. Fruit nutrient concentration values will be tabulated and analyzed with SAS and JMP Pro statistical software packages; the rootstock genotype will be treated as the main effect in a randomized complete block analysis. Rootstock genotype means will be used in a multivariate analysis to generate correlation matrices and two-way similarity cluster diagrams based on genotype and variable similarities.We will use those means to validate the effect of the presence/absence of specific DNA markers linked to nutrient uptake and other organic friendly root traits. Relevant validated markers will be used to query a larger rootstock pool to search for new material to test under organic management. Objective 3We will compile the information from our field trials to understand their productivity performance in relation to innate nutrient uptake potential. From this information we will first develop more accurate nutrient management recommendations for organic growers in the Northeast. We will then use this information to develop an online smart rootstock selection tool that will consider soil type, scion cultivar vigor, climate vigor and grower nutrient input plan to select/recommend the best rootstocks for each new organic orchard. To develop the selection tool, we will categorize all the soil types in NY State into vigor classes based on nitrogen supplying power. For growers outside of NY State we will request that they input a soil vigor. We will also categorize scion varieties into vigor classes. We will develop a climate vigor index to categorize growing locations based on heat-unit accumulation during the growing season. Lastly we will allow growers to input the nitrogen fertilization plan they will implement. These assessments to vigor will be used to then pair a Geneva® rootstock with sufficient vigor that will perform well under those conditions. For this project we will develop the smart rootstock selection tool for the Eastern USA but we plan to extend this tool to other production areas if cooperators from other states are interested. Progress 09/01/21 to 08/31/24 Outputs Target Audience:Organic apple growers in the eastern USA Changes/Problems:In the spring of 2022, a severe outbreak of fire blight was experienced across NY State. One of the research plots for this project was severely affected by fire blight with the loss of some trees. However, we were able to continue with the experiment and concluded that trial in 2024 and are in the process of publishing the final results this winter. We had planned a field day at this experiment but with the fire blight damage we decided it would not be helpful to bring organic growers to the site. Thus, we chose to publish our project results in the Fruit Quarterly Magazine and give our rootstock recommendations in print rather than at a field day. What opportunities for training and professional development has the project provided?Through this project we have trained 1 graduate student (MS) (Julie Cardon) who completed her degree in July of 2024. Her thesis title (Characterizing rhizosphere microbes and metabolites of rootstocks that differ in their resistance to apple replant disease.)is direclty related to this project. We have also partially completed the training of 1 PhD graduate student (Davis Upchurch) who is studying virus effects on rootstock performance. This project has contributed to the post doctoral training of onePost Doctoral Researcher (Brian Lawrence) in our program. How have the results been disseminated to communities of interest?1. We have published recommendations from this project for organic apple growers in the Fruit Quarterly Magazine in 2024. This magazine is sent to all apple growers in NY and MI and is available to apple growers world wide online. 2. We have developed a website with the characteristics of the Geneva rootstocks that will help all apple growers chose the best rootstock for their situation. 3. While online tools can provide an initial idea of what rootstock choices to make, the investigators had an additional idea on how to provide long lasting information to organic apple growers in the North-East. Perhaps the best way for an organic apple grower to know what rootstocks work best is to experience them first-hand in their specific locations. Therefore, after the first two years of nutrient analysis data we identified some of the rootstock choices the best fire blight and replant disease tolerant rootstocks (G.257, G.484, G.66, G.41, G.935 and G.969) which also featured some advantageous nutrient uptake profiles and combined them with some of the best scab resistant scion varieties (requiring less sprays) to make apple trees that could be distributed to organic apple growers to test them. The process of making trees in the nursery lasted two years (we had to grow the rootstocks first - year 1 - and then graft the scion and grow the trees - year 2) The scions that were chosen were Triumph (https://mnhardy.umn.edu/triumph) a scab resistant apple bred by the University of Minnesota and Story® also known as Innored (https://acnursery.com/product/story-inored-cv-pppp22794/) another high quality scab resistant apple. We had about 2,000 trees (1,000 for each scion variety) which were propagated on 7 different apple rootstocks. These trees were distributed in the Spring-Summer of 2024 to 12 different organic growers in four different states including NY, MI, ME, VT and very different size and type operations including multi-generation family farms, Amish, large companies with organic operations, and scientific advisors. What is characteristic about communities that work with organic principles is that they support each other in online forums and by word of mouth. The planting of these trees will likely provide more localized, experience-based communications. While the duration of this grant is over, the impact of these plantings will last for many years to come. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? Goal 1 report: In the planning phase of establishing an organic orchard, growers need to make some critical decisions with regards to what type of scion variety is going to be planted and just as important what type of rootstock is going to support the growth and production of that variety. While the choice of scion variety is not part of this work, it cannot be overlooked as the whole tree (scion and rootstock) is what is finally deployed and starting up with a disease resistant scion (apple scab, fire blight, bacterial spot etc.) will certainly enhance the profitability of the operation. As far as the choice of rootstock there are some important considerations that have become evident because of this research: 1.Disease resistant apple rootstocks with generally outperform traditional apple rootstocks when it comes to tree survival and productivity. The North-East is endemic to one of the most devastating apple diseases called fire blight caused by the bacterium Erwinia amylovora. In our plantings we have witnessed scions that were severely impacted by this disease and yet when the rootstocks were of resistant type the whole tree did not die and was able to be recovered in successive years. Other soil diseases related to replant disease were also important as we could see the difference between sensitive and susceptible rootstocks in the way they grew and yielded fruit. 2.More vigorous trees that are also precocious are desired in organic production. Apple trees under organic management are challenged by weed competition in the root zone around the tree. This competition will decrease the size and productivity of apple trees and many organic apple growers have resorted to substituting dwarfing precocious rootstocks that are sensitive to this competition with vigorous, non-precocious (productive) rootstocks to overcome this weakness. As it turns out, this is a very poor choice because it ends up delaying production of the orchard by several years and reducing apple yields favoring the production of unfruitful wood. Our experiments showed that newly released rootstocks such as G.484, G.257 and G.890 will provide the extra growth needed to support a very productive orchard when compared to traditional choices such as M.7, MM.111, B.118 and MM.106. Over the long-term live of an organic orchard even small increases in the productivity per tree translates in huge gains in profitability. 3.More resilient rootstocks to adverse climate events can be deployed in organic apple orchards. While this project did not focus on adverse climatic events and the length of the grant period (3-4) years did not permit to observe once in a decade events it still provided some insight into climatic considerations that organic apple grower should take into account when choosing a rootstock. Adverse climatic events that affect rootstocks include: excessive rain and flooding, extreme drought periods, early winter cold snaps, extreme mid-winter cold, mid-winter warming period followed by sudden cold snap. There are rootstocks (G.41, G.935, G.202) that seem to survive long periods of flooding when compared to the traditional rootstocks (M.9, B.9, M.26, and M.7). This tendency is likely partially due to tolerance to crown rot caused by phytophthora species which attacks rootstock tissues weakened by the lack of oxygen. Tolerance to mid-winter and early winter cold events has been described in apple rootstocks G.41, G.202, G.935 and G.214. Tolerance to drought by apple rootstocks is a very complex trait and is still being investigated. 4.Fruit quality characters such as fruit size, color, maturity and internal quality can be drastically influenced by apple rootstocks under organic management. Similarly to what happens under conventional management, the choice of apple rootstocks has proven to increase the average size of fruit (G.41, G.257 or G.814) while maintaining high production. Apple rootstock G.11 has been shown to increase maturity and decrease time to pick. Apple rootstocks G.214 and G.969 have been proven to decrease bitter pit of apples significantly. Overall, under goal 1 we have determined that several Geneva® apple rootstocks are a better choice for organic apple growers, where the ultimate choice is dependent on several factors that are outlined in goal 3. Goal 2 report: The process of determining rootstock effects on nutrient uptake under organic management involved collecting, processing and analyzing over 5,200 leaf and fruit samples over 4 years. The results were summarized in a few presentations to apple growers and scientific conference and two manuscripts (Apple rootstocks affect mineral nutrient uptake in organic orchards - presented at the Mineral Nutrition of Fruit Trees Symposium, International Society for Horticultural Science) which compared the results from field trials in three different locations over several years. We monitored the content of phosphorous (P), potassium (K), calcium (Ca), sulfur (S), iron (Fe), manganese (Mn), and copper (Cu) in leaves and fruit of three experimental orchards using Energy-Dispersive X-ray Fluorescence (XRF) for two seasons (2022-2023). Two of the plantings (Geneva and Ithaca, NY) are part of the 2015 organic NC-140 trial and feature 11 commercial rootstocks grafted with the scab resistant scion cultivar \'Modi®\', whereas the third trial established in 2013 in Albion, NY features 18 commercial and experimental rootstocks grafted with \'Crimson Crisp\'. In Geneva, the 2022 and 2023 XRF data showed that Geneva®(G) 969, G.41, G.935, and G.222 contained greater leaf S which has been shown to have a strong correlation with leaf N concentration. In Ithaca, the 2022 and 2023 XRF data showed that G.890 had consistently higher S, P, and K levels. Rootstocks G.11 and G.214 displayed lower levels of S in both locations and both years. Other nutrient levels were somewhat inconsistent between locations and years in the NC-140 trials. In the Albion organic trial rootstocks, G.484, G.890, G.222, and CG.5030 displayed higher levels of leaf P and S (measured by ICP in 2014 and 2016). Rootstock CG.4003 displayed consistently higher levels of Ca in leaves and fruit in the XRF data, as well as the ICP data. Multivariate analysis using mean ICP and XRF leaf nutrient data found significant similarities for Ca and K perhaps validating the usefulness of the XRF instrument to calculate rootstock influenced K/Ca ratios. While seven rootstocks were common at all experimental locations, the interaction of different scion cultivars, ground floor management, soil type, and fertilizer applications may have contributed to the low levels of correlation among other nutrients. Due to their overall nutrient use efficiency, G.890, G.484, G.222, and perhaps G.935 are well suited for organically managed orchards. Goal 3 This goal is reported below in the extension of results section. Publications Type: Peer Reviewed Journal Articles Status: Published Year Published: 2024 Citation: Al Farqani, A., Cheng, L., Robinson, T.L. and Fazio, G. 2024. Effect of soil solution pH on root architecture and dynamics of root distribution of four apple rootstocks grown in an aeroponics nutrient misting system. Front. Plant Sci. 15:1351679. doi: 10.3389/fpls.2024.1351679 Type: Theses/Dissertations Status: Published Year Published: 2024 Citation: Cardon, J. 2024. Characterizing rhizosphere microbes and metabolites of rootstocks that differ in their resistance to apple replant disease. M.S. Thesis, Cornell University, Ithaca, NY. Type: Peer Reviewed Journal Articles Status: Published Year Published: 2024 Citation: Gonzalez, L., Ho, S-T, B.J. Rickard, G. Fazio, G. Reig, J. Lordan, S.A. Hoying, M.J. Fargione, M. Miranda Sazo, T.L. Robinson. 2024. Estimated Economic Impacts of Fire Blight on Long-Term Orchard Economic Performance with Susceptible and Disease Resistant Rootstocks. Scientia Hort. 337 (2024) 113478 Type: Peer Reviewed Journal Articles Status: Published Year Published: 2024 Citation: Ho, S.-T., L. Gonzalez, B.J. Rickard, G. Reig, J. Lordan, G. Fazio, S.A. Hoying, M. Fargione, M. Miranda Sazo and T.L. Robinson. 2024. Effects of Cultivar, Training System and Rootstock on Long-term Economic Performance of Apple Orchards in the Northeastern U.S. Scientia Hort. 332, 2024, 113194. Type: Other Journal Articles Status: Published Year Published: 2024 Citation: Fazio, G., G. Peck, T. Robinson. 2024. Rootstocks for organic apple orchards. Fruit Quarterly 32(3):4-7. Type: Other Journal Articles Status: Published Year Published: 2024 Citation: Robinson, T.L., L. Cheng, G. Fazio, C.B. Watkins, M. Miranda Sazo, L. Gonzalez, B. Lawrence, Craig Kahlke, Mike Basedow, P. Francescatto, A. Al Farqani and S. Lopez. 2024. Management of Honeycrisp apple trees for maximum sustained yield and minimal bitter pit. Fruit Quarterly 32(1): 4-10. Type: Other Journal Articles Status: Published Year Published: 2024 Citation: Robinson, T.L., L. Gonzalez Nieto, S.-T. Ho, B.J. Rickard, G. Reig, J. Lordan, G. Fazio, S.A. Hoying, M.J. Fargione, M. Miranda Sazo. 2024. Apple orchard economics: Effects of cultivar, planting density and rootstock. Fruit Quarterly 32(2): 4-11. Type: Other Journal Articles Status: Published Year Published: 2024 Citation: Robinson, T.L., Gonzalez, L., Ho, S-T, B.J. Rickard, G. Fazio, G. Reig, J. Lordan, S.A. Hoying, M.J. Fargione, M. Miranda Sazo. 2024. Economic impact of fire blight with susceptible and resistant apple rootstocks. Fruit Quarterly 32(3):15-20. Type: Conference Papers and Presentations Status: Awaiting Publication Year Published: 2024 Citation: Fazio, G., G. Peck, T. Robinson. 2024. Apple rootstocks affect mineral nutrient uptake in organic orchards. Acta Hortic. (in press) Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Cardon, J., Thies, J., Peck, G., Fazio, G., Robinson, T. 2024 Apple Rootstocks Affect Soil Rhizosphere Microbial Communities and Root Exudate Composition HortScience 59(9) Supplement p423 (Abstr.) Type: Websites Status: Published Year Published: 2024 Citation: https://ctl.cornell.edu/wp-content/uploads/2024/08/Geneva-Rootstocks-Comparison-Chart_Web_Updated-8-2024_new.pdf Progress 09/01/22 to 08/31/23 Outputs Target Audience:Organic apple growers in the eastern USA Changes/Problems:A severe spring frost in May 2023 severly reduced the crop in the organic rootstock plot planted in 2015. What opportunities for training and professional development has the project provided?This project has given opportunities so far for 2graduate students (Julie Cardon and Davis Upchurch) whose thesesareon apple rootstock performance in organic management systems and soil microflora communities associated with each rootstock. One post doctoral researcher (Luis Gonzalez) has also been a part of the organic rootstock trial planted in 2015. How have the results been disseminated to communities of interest?In 2023the project leaders gave 2presentations to apple grower groups to disseminate the results of this project. We have also published 1articles in a natinal grower magazine about our work on rootstocks for organic apple growers. We have also released 3 new apple rootstocks that will be useful to organic apple growers in the next 10 years. What do you plan to do during the next reporting period to accomplish the goals?Next year we will study soil microflora as influenced by rootstock genotype in organic soils. We will also study root exudates from different rootstock genotypes. We will also study molecular markers of rootstock traits associated with high performance in organic management sustems. Impacts What was accomplished under these goals? Objective 1. An organic apple rootstock trial was conducted at Geneva NY. Tree size (TCSA) after 9 years reflects 5 groups of vigor: with G.16 and G.222 being the most dwarfing stocks; G.969, G.11, G.214, and G.935 slightly more vigorous; G.41 and M.9 were more vigorous; a semi-dwarfing group of G.202 and G.30; and finally, a semi-vigorous stock of G.890. TCSA increment roughly followed stock vigor. In 2023, G.16, G.935 and G.890 all had the most suckers on average (\>4). Tree survival after 9 growing seasons was lowest for G.16 followed by G.935. Yield in 2023 was severely reduced due to frost damage in May 2023.Since yield was extremely low in 2023, 10-year cumulative measurements were similar to 2022, with the greatest cumulative yield with G.890 followed by G.41, G.30 and G.214. The lowest cumulative yield was with G.222 and G.16. Cumulative yield efficiency was higher with G.16 followed by G.214, G.11, G.935, and G.41 (\> 2.0 kg/cm2 TCSA). After 9 growing seasons, G.935 and G.41 are promising rootstocks for organic production of Modi apple in a high-density system. For a medium density system, G.890 has shown good promise. A new rootstock trial was planted in a certified organic site at the Geneva experiment station in the spring of 2022. The trial compares 15 different rootstocks in a replicated design. In both 2023we sampled the soil adhering to the roots of these trees for DNA extraction in order to characterize both bacterial and fungal microorganisms in the rhizosphere of the rootstocks in our research. We also established an aeroponic greenhouse trial to sample rhizodeposits from 6 of the rootstocks used in the orchard trial, with the aim of characterizing plant metabolites which are exuded from roots with untargeted HPLC/LCMS. Objective 2. We have measured the effect of rootstock on mineral concentration in the peel of \'Honeycrisp\' in 2 plots in NY State (Geneva 2010 Honeycrisp plot and Geneva 2014 Honeycrisp plot). We correlated the K/Ca ratio in the fruit peel) and bitter pit of Honeycrisp apple (Robinson and Fazio, 2022). The results of these studies support our earlier results that showed rootstock genotype has a large influence on bitter pit incidence and on the fruit nutrient levels of the peel (Fazio et al., 2019). In these studies, we have confirmed that B.9 in most cases has low bitter pit incidence. We have also identified several new Geneva® rootstocks which have low bitter pit incidence (G.214, G.969, G.935 and G.65) and other rootstocks that have high bitter pit incidence (G.210 and M.7). We are in the process of writing several research articles to summarize and extend our information on rootstocks and mineral nutrient profiles. Publications Type: Journal Articles Status: Published Year Published: 2023 Citation: Bradshaw, T., Autio,W., Blatt, S., Clements, J., Einhorn, T., Elkins, R., Fallahi, E., Francescatto, P., Lordan, J., Minas, I., Peck, G., Robinson, T. and Yao S.. 2023. Performance of Modi� apple trees on several Geneva rootstocks managed organically: Five-year results from the 2015 NC-140 Organic Apple Rootstock Trial. Journal of the American Pomological Society 77 (1):14-27. Type: Journal Articles Status: Awaiting Publication Year Published: 2023 Citation: Ho, S.-T., L. Gonzalez, B.J. Rickard, G. Reig, J. Lordan, G. Fazio, S.A. Hoying, M. Fargione, M. Miranda Sazo and T.L. Robinson. 2023. Effects of Cultivar, Training System and Rootstock on Long-term Economic Performance of Apple Orchards in the Northeastern U.S. Scientia Hort. (In press) Type: Journal Articles Status: Published Year Published: 2023 Citation: Gonzalez, L., G. Reig, J. Lordan, M. Miranda Sazo, S.A. Hoying, M.J. Fargione, G.H. Reginato, D.J. Donahue, P. Francescatto, E. Casagrande, G. Fazio, T.L. Robinson. 2022. Long-term effects of rootstock and tree type on the economic profitability of Gala, Fuji and Honeycrisp orchards performance. Scientia Horticulturae 318, 2023, 112129, https://doi.org/10.1016/j.scienta.2023.112129. Type: Journal Articles Status: Published Year Published: 2023 Citation: Fazio G, Mazzola M, Zhu Y. 2023. Genetic analysis of resistance to pythium ultimum a major component of replant disease in apple rootstocks. Journal American Pomological Society. 77:28-37. Type: Journal Articles Status: Published Year Published: 2023 Citation: Emeriewen OF, Reim S, Richter K, W�hner T, Flachowsky H, Aldwinckle H, Peil A, Fazio G. 2023. The fire blight resistance qtl on lg7 of malus x robusta 5 is not dependent on the avrrpt2ea 156 s/c amino acid switch. Journal of Plant Pathology.8. Type: Journal Articles Status: Published Year Published: 2023 Citation: Fazio, G. and T. Robinson. 2023. New releases from the Geneva� apple rootstock breeding program. Fruit Quarterly 31:(1):29-33. Type: Journal Articles Status: Published Year Published: 2023 Citation: Londo, J.P., L. Gonzalez, and T.L. Robinson. 2023. Characterizing Cold Hardiness Dynamics in Apple Rootstocks. Fruit Quarterly 31:(1):4-7. Progress 09/01/21 to 08/31/22 Outputs Target Audience:Organic apple growers in the eastern USA Changes/Problems:In 2021 after we had submitte this proposal a severe fire blight epidemic killed one of the organic apple rootstock trials we had planned to use in this project. That loss was disappointing but the other trials we have will allow us to successfully complete the project. What opportunities for training and professional development has the project provided?This project has given opportunities so far for 1 graduate student (Julie Cardon) whose thesis is on organic apple rootstock performance. One post doctoral researcher (Luis Gonzalez) has also been a part of the organic rootstock trial planted in 2015. How have the results been disseminated to communities of interest?In 2022 the project leaders gave 3 presentations to apple grower groups to disseminate the results of this project. We have also published 2 articles in a natinal grower magazine about our work on rootstocks for organic apple growers. We have also released 3 new apple rootstocks that will be useful to organic apple growers in the next 10 years. What do you plan to do during the next reporting period to accomplish the goals?Next year we will study soil microflora as influenced by rootstock genotype in organic soils. We will also study root exudates from different rootstock genotypes. We will also study molecular markers of rootstock traits associated with high performance in organic management sustems. Impacts What was accomplished under these goals? Objective 1. An organic apple rootstock trial was conducted at Geneva NY.After 8 years tree size (TCA - cm2), could be separated into five different groups. The most dwarfing stocks in this trial are G.16 and G.222, followed by a slightly more vigorous group of G.969, G.214, G.11, G.935. A more vigorous group consisted of G.41 and M.9. A semi-dwarfing group comprises G.202, and G.30. In the semi-vigorous category was G.890 which was the most vigorous stock in the trial. Tree survival was lowest for G.16 followed by G.222. G.890 had the most root suckers followed by G.935, G.30 and G.16. All other stocks had less than 1 sucker per tree.The most productive rootstock in 2022 was G.214 followed by G.890, G.16, G.41, G.969, G.202, G.222, M.9 and G.11. However, when production is expressed in terms of yield efficiency, G.16 was the most efficient stock, followed by G.214 and G.222, G.969, G.41 and G.11. G.890, G.30 and G.202 were the rootstocks with the lowest yield efficiency in 2022.There were differences among stocks in fruit size in 2022. M.9 and G.41 had the largest fruit size followed by G.202, G.890, G.11 and G.969. G.935 and G.30 were the rootstocks with the smallest fruit size. Cumulative yield was greatest with G.890 followed by G.41, G.30 and G.935. The lowest cumulative yield was with G.222 and G.16. Cumulative yield efficiency was greatest with G.935 followed in order by G.214, G.41, G.11, G.16, G.969, G.222, G.30, M.9 and last was G.202 and G.890. Early conclusions indicate that G.935 and G.41 are promising rootstocks for organic production of Modi apple in a high-density system. For a medium density system, G.890 has shown good promise. A new rootstock trial was planted in a certified organic site at the Geneva experiment station in the spring of 2022.The trial compares 15 different rootstocks in a replicated design. In both 2022 we sampled the soil adhering to the roots of these trees for DNA extraction in order to characterize both bacterial and fungal microorganisms in the rhizosphere of the rootstocks in our research. We also established an aeroponic greenhouse trial to sample rhizodeposits from 6 of the rootstocks used in the orchard trial, with the aim of characterizing plant metabolites which are exuded from roots with untargeted HPLC/LCMS. Objective 2.We have measured the effect of rootstock on mineral concentration in the peel of \'Honeycrisp\' in 2 plots in NY State (Geneva 2010 Honeycrisp plot and Geneva 2014 Honeycrisp plot). We correlated the K/Ca ratio in the fruit peel) and bitter pit of Honeycrisp apple (Robinson and Fazio, 2022). The results of these studies support our earlier results that showed rootstock genotype has a large influence on bitter pit incidence and on the fruit nutrient levels of the peel (Fazio et al., 2019). In these studies, we have confirmed that B.9 in most cases has low bitter pit incidence. We have also identified several new Geneva® rootstocks which have low bitter pit incidence (G.214, G.969, G.935 and G.65) and other rootstocks that have high bitter pit incidence (G.210 and M.7).? Publications Type: Journal Articles Status: Published Year Published: 2022 Citation: Fazio, G., Aldwinckle, H.S. and Robinson, T.L. 2022. Selection of apple rootstock breeding families for Phytophthora crown rot resistance. Acta Hortic. 1346, 717-722 DOI: 10.17660/ActaHortic.2022.1346.90 https://doi.org/10.17660/ActaHortic.2022.1346.90 Type: Journal Articles Status: Published Year Published: 2022 Citation: Robinson T. and G. Fazio. 2022. Rootstock affects fruit nutrient profile and bitter pit incidence of apple. Acta Hortic. 1333, 373-378. Type: Journal Articles Status: Published Year Published: 2022 Citation: Robinson, T.L. and Fazio, G. 2022. Rootstock evaluation should not only measure yield efficiency but also potential yield and crop value at the optimum projected spacing. Acta Hortic. 1346, 775-782 DOI: 10.17660/ActaHortic.2022.1346.99 https://doi.org/10.17660/ActaHortic.2022.1346.99 Type: Journal Articles Status: Published Year Published: 2022 Citation: Fazio, G., J.C. Bettoni, L. Carvalho Costa, O.P. Hurtado-Gonzales, M. Al Rwahnih, A. Steinberger, A. Nedrow, G.M. Volk, S. Adams, R. Adams, T. Robinson. 2022. Virus Studies in the Geneva� Apple Rootstock Breeding Program. Fruit Quarterly 30:(2):4-6. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Miranda Sazo, M., L. Cheng and T.L. Robinson. 2022. Nutrient uptake and accumulation of Honeycrisp trees as affected by four rootstocks from establishment (2017) to maturity (2021). Abstracts of the ASHS Annual Meeting in Chicago IL. Aug. 1, 2022 (50 people Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Robinson, T. and G. Fazio. 2022. The role of rootstock on fruit nutrient profile and bitter pit incidence of apple. Abstracts of the ASHS Annual Meeting in Chicago IL. July 31, 2022 (60 people) Type: Journal Articles Status: Published Year Published: 2022 Citation: Fazio, G. and T.L. Robinson. 2022. Time analysis of rootstock mediated nutrient transport in Honeycrisp. Acta Hortic.1333, 405-412 Type: Journal Articles Status: Published Year Published: 2022 Citation: Fazio, G. and Robinson, T.L. 2022. Apple rootstocks can modulate the chilling requirements of grafted scions. Acta Hortic. 1346, 723-728 DOI: 10.17660/ActaHortic.2022.1346.91 https://doi.org/10.17660/ActaHortic.2022.1346.91

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The Divergent Paths of Organic Transition: Best Management Practices for Initial Years of Organic Vegetable Fields in Southeastern U.s.

Accession No.	1027231
Project No.	ALA0Andre
Agency	NIFA ALA\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2021-51106-35568
Proposal No.	2021-04817
Start Date	01 SEP 2021
Term Date	31 AUG 2025
Grant Amount	$595,000
Grant Year	2021
Investigator(s)	da Silva, A.; Majumdar, AY, .; Li, ST, .; Kemble, JO, .; Chicas-Mosier, AN, .
Performing Institution	AUBURN UNIVERSITY, 108 M. WHITE SMITH HALL, AUBURN, ALABAMA 36849

NON-TECHNICAL SUMMARY

This is an Organic Transitions Research-led project to develop best management practices that mitigate risks of crop failure for initial years of organic transitioning fields and promote sustainable intensification of organic vegetable production. Best management practices for new organic systems will be determined based on agricultural and environmental aspects, such as soil health, weeds, insects, disease, crop development, yield, and quality. In addition, the feasibility for growers\' adoption will be considered and stakeholders\' involvement in planning, development, and implementation of outputs will be a key aspect of this project. As a result, Auburn University and the Alabama Cooperative Extension System will create guidelines for more effective land use, pre-planting land preparation, and weed management during the transition of organic vegetable fields. Conventional and novel outreach approaches will convey information generated from proposed activities to our clients, growers, and stakeholders. A project evaluation will measure the immediate and long-term impact. Ultimately, the certified organic field and proposed new capacity building initiative will ensure the sustainability of the project scale. The objectives of this project are in line with the Strategic Plans of USDA and the Priority Areas of the Organic Transitions.

OBJECTIVES

Failure is frequently reported by vegetable growers during the initial years of an organic transitioning field; however, there is not a single guide with best management practices during the implementation of organic fields for vegetable production. While the majority of guides emphasize the required practices for organic certification, there is a clear lack of guidance on practices that minimize the risks of outbreaks and are environmentally friendly. Under these contexts, the overall project goal is to identify potential agricultural and environmental threats during the transition of organic fields for vegetable production, and to develop resilient strategies that mitigate risks of failures and improve the sustainable intensification of organic vegetable systems in the southeastern U.S. The project specific objectives are:Objective 1: Document potential risks of crop failure and determine benefits of alternative use of land for the first year of new vegetable organic fields. Objective 2:

Evaluate the impact of pre-planting land preparation on soil health, plant development, and crop yield for the initial years of an organic field. Objective 3: Evaluate the effectiveness of weed control programs for key species populations during the initial years of an organic vegetable transition. Objective 4: Development of best management practices for organic vegetable transitioning fields. Objective 5: Extension, education, and internal project evaluation.

APPROACH

Objective 1:Document potential risks of crop failure and determine benefits of alternative use of land for the first year of new vegetable organic fields. A one factorial experimental design will be used to evaluate three approaches of land use in a randomized complete block arrangement. Land use approaches will consist of fallow ground with periodic tillage, growing of a cover crop (i.e., sorghum sudangrass), and growing of a vegetable crop (i.e., tomato). Fallow ground treatment will consist of continuous use of bare ground during the entire season with constant soil tillage to control weeds. For the cover crop and vegetable crop treatments, a pre-planting land preparation of soil tillage and cultivation will be conducted. Sorghum sudangrass will be mechanically planted using a four-row planter. Plastic mulching beds with drip irrigation will be used for tomato plants that will be hand-transplanting. Our hypothesis is that growing cover crop during year 1 of organic transition builds soil health, suppresses weeds, and minimize risks of crop failure compared to fallow ground and production of vegetable crops. This means delaying cash crop by one year may provide long-term benefits. Objective 2: Evaluate the impact of pre-planting land preparation on soil health, plant development, and crop yield for the initial years of an organic field. For experiment 1, a one factorial experimental design of three strategies of pre-planting land preparation for organic tomato production will be randomized in a complete randomized block arrangement. The first pre-planting land preparation strategy will consist of conventional practices (i.e., soil tillage and cultivation), and will occur after soil incorporation of a winter cover crop. Plastic mulching beds of 6-ft center to center spacing will be used for tomato seedlings transplanting. The second strategy of pre-planting land preparation will consist of direct planting of tomato seedlings on a 3-ft row spacing, after the laying down of rye, using a roller crimper. The third strategy is a combination of treatments one and two, in which the winter cover crop will be laid down for the entire field using a roller crimper, but only incorporate in the soil in strip beds, that will consist of a narrow (18 in) plastic bed formed for a 3-ft center to center bed spacing. For experiment 2, a one factorial experimental design of two strategies of pre-planting land preparation for sweet corn production will be randomized in a complete randomized block arrangement. The first pre-planting land preparation strategy will consist of the soil incorporation of a winter cover crop (i.e., rye), followed by conventional practices of soil tillage and cultivation. The second pre-planting land preparation strategy will consist of the direct planting of sweet corn seeds after the laying down of rye. Our hypothesis is that different strategies will lead to different impacts on soil health, weeds pressure, and disease/insect. These are the major issues for organic transition fields. Consequently, our proposed strategies may influence vegetable crops growth, yield, and quality parameters. Objective 3:Evaluate the effectiveness of weed control programs for key species populations during the initial years of an organic vegetable transition.A two factorial experiment design of two mulching systems and four weed control treatments during the vegetable season of new organic fields will be randomized in a complete randomized block arrangement. Mulching treatments will consist of using plastic mulching and no mulching (bare ground). Weed control treatments will consist of mechanical control, using a Model CS and/or Eco Weeder cultivator (Hillside Cultivar Company LLC, Lititz, PA), use of organic herbicides, such as Matran 5 (EcoSMART Technologies, Inc., Franklin, TN), Weed Zap (JH Biotech, Inc., Ventura, CA), and Racer (Falcon Lab LLC, Wilmington, DE), a combination of mechanical control and organic herbicides, and no weed control (check).After soil incorporation of a winter cover crop (i.e., rye), the organic field will be tilled and cultivated. Plastic beds will be laid for the plastic mulching treatment, while raised bare ground rows will be prepared for the no mulching treatment. Yellow squash will be hand-transplanted in all plots. Both mechanical and organic herbicide treatments will be weekly applied, while the combined mechanical and organic herbicide treatment will intercalate each in a every other week interval. No control treatment will receive no management and will be used as a check. We hypothesize that combinations of mulching and weed management will differently impact weed pressure, consequently, minimize risks of failure and maximize crop growth and yield. Objective 4:Development of best management practices for organic vegetable transitioning fields. Field experiments of objective 4 will be conducted simultaneously with previous objectives, in which experiments of objectives 1, 2, and 3 will receive an additional treatment consisting of conventional growth of tomato, sweet corn, or yellow squash, as appropriate. The additional treatment will allow for orthogonal contrasts to be used, thus,best treatment combinations from objectives 1, 2, and 3 can be compared against the conventional crop system treatment. Those comparisons will allow us to determine the best management practices for fields in transition from conventional to organic vegetable production. Combinations of best treatments from objectives 1, 2, and 3 will depend on performance of treatments within each objective and stakeholder feedback. Objective 5:Extension, education, and internal project evaluation. This project will use several approaches to convey information generated from proposed activities to our clients, growers, and stakeholders. We will use the stakeholder advisory panel, described in section 3a, to actively involve stakeholders, growers, and researchers with the project team for planning, development, and implementation of outputs. In addition, we will use the Alabama Cooperative Extension System (ACES) to increase our targeted audience. Our research team, comprised of four members of the Commercial Horticulture Team from ACES, are confident of identifying numerous opportunities to present information in conventional face-to-face format. Thus, we will use the program model proposed in figure 6, which was based on concepts from the Success Outcome Markers in Extensionby Rockwell et al. (2003) and transformational education model by Blewett et al. (2008), to achieve rapid transfer of results. This approach will take a four-step process:technology awareness after identification of appropriate solutions.technology demonstration on research farms.technology refinement (facilitation with key farmers).full technology adoption and impacts.An additional extension approach used relies on communication and marketing principles, and we propose to use the approaches below to add to knowledge infrastructure for long-term results:Digital mediaSocial media for social learning in online grower communitiesFarming Basics Incubator \"Pilot\" ProgramField demonstration and training for capacity buildingPublications and conferencesProject evaluation will be reported in the form of colorful annual reports, online interactive data charts, andimpact videos. Project evolution will be focused on gathering quantitative as well as qualitative information leading to a mixed-method evaluation approach (Table 1) and utilization-focused evaluations that bring transparency to the entire process. We will use a variety of evaluation techniques (Table 2) that include printed surveys and electronic feedback systems with standardized questionnaires. Data will be retained in spreadsheets and major findings used to improve the deliverables of the project. The detailed evaluation plan is in table 3 and emphasizes the removal of known barriers and documentation of new needs. Progress 09/01/22 to 08/31/23 Outputs Target Audience:Our project remains focused on serving the growing organic community in Alabama, where interest in organic production has been increasing. While there has been a noticeable rise in demand for organic produce in the state, we have not yet measured the number of growers transitioning to organic production. Our long-term objective is to expand production within organic systems. Certification continues to present challenges, especially as we observe that the majority of the organic community is made up of small-scale and disadvantaged growers. Our target audience continues to include both experienced and beginner growers, as well as regional extension agents, specialists, and researchers. Changes/Problems:In 2023, unfavorable weather conditions significantly impacted crop growth and development. Our research team did everything possible to minimize the damage caused; however, it stillled to the failure of harvesting. In 2024, the authors changed the area of the experiment within the field as a tentative to success. What opportunities for training and professional development has the project provided?In 2023, training and professional development were provided in an extension meeting, and data from 2022 was shared in growers\' conferences, such as the Southeast Fruit and Vegetable Conference and the Alabama Fruit and Vegetable Growers Association Conference. Extension presentations included: da Silva, A.L.B.R., D. Lawrence (2023). Growing specialty crops. In Operation Grow Boot Camp, Montgomery, AL. da Silva, A.L.B.R., C. Rodrigues (2023). Food production systems. In Natural Resource Outreach Event - \"Small Landowner Workshop\", West Blocton, AL. de Barros, M.F.L., A.L.B.R. da Silva (2023). Vegetable production for open markets. In 2nd Annual Food Systems Development Workshop, Linden, AL. da Silva, A.L.B.R., 2023. Niche crops for production in north Alabama. Cullman County Meeting. da Silva, A.L.B.R. 2023. Making the most of your farm: Best management practices for vegetable production. Gulf Coast Fruit and Vegetable Growers Meeting 2023. How have the results been disseminated to communities of interest?As mentioned previously, results have been disseminated to communities of interest throughout extension activities. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? In 2023, field experiments for Objectives 2 and 3 were initiated; however, unfavorable weather conditions significantly hindered crop growth, leading to the failure of these objectives prior to harvest. Despite replanting the experiments, the delayed planting dates resulted in suboptimal growth conditions, preventing the crops from reaching maturity and rendering the collected data unrepresentative of typical agricultural conditions. As a result, the data was discarded. Nevertheless, the activities outlined in Objective 5 were successfully carried out, including the development and dissemination of extension and educational materials as planned. Publications Type: Other Status: Published Year Published: 2023 Citation: Oliveira, S., R. Pelvine, C. Rodrigues, C. East, A.L.B.R. da Silva. 2023. Lettuce cultivars for open-field organic systems. Alabama Cooperative Extension System. Extension Bulletin ANR-2964. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Nakazawa, P., W. Foshee, E. Torres-Quezada, A.L.B.R. da Silva. 2023. Strategies of irrigation scheduling for organic tomato production. Southern Region American Society of Horticultural Science. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: da Silva, A.L.B.R. 2023. Supporting a vegetable industry with research and extension but without forget teaching. American Society of Horticulture Science. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: da Silva, A.L.B.R., A. Dorminey, C. Rodrigues, A. Majumdar, S. Li, W. Foshee. 2023. The divergent paths of organic transition: Best management practices for initial years of organic vegetable fields in southeastern U.S. Organic Programs Project Directors Meeting. **Progress** 09/01/21 to 08/31/22 **Outputs** Target

Audience: This research project has a continuous process that will target the entire organic community. While our long-term goal is to increase the overall yield in organic production systems and certification of organic vegetable fields, our targeted audience in the first year was:\| Gowers in the first year of organic transition at experienced and beginner level Regional extension agents, specialists, and researchers Students at undergraduate and graduate level Changes/Problems:There was no change or problem faced in our project. However, we sight barriers in some activities due to the increased cost of inputs. What opportunities for training and professional development has the project provided? The project has provided a field day to growers, listed in the accomplishments. The Field day \"Vegetable Crop Conventional & Organic\" was conducted on May 31, 2022, and received 89 guests, including growers, regional agents, and members of organic companies. The project also allowed us to host growers in our organic unit at the E.V. Smith Research and Extension Center from Auburn University, local of the field day, where individual meetings were conducted to show clients the challenges of transition and best management practices that should be used due the transition. One-on-one farm visits were also conducted. Ultimately, we were invited to host a section titled \"Organic Transition\" at the Alabama Fruit and Vegetable Growers Conference in February 2023. How have the results been disseminated to communities of interest? Information generated in our project was disseminated to the communities as previously described. It was shared in form of: Extension publications Website news/blog articles Field days One-on-one meeting What do you plan to do during the next reporting period to accomplish the goals? During next year, experiments from objectives 2 and 3 will be conducted. We will release new extension publications, continue to do farm visits, and release new research publications. We will host an \"Organic transition\" section at the Alabama Fruit and Vegetable Growers Conference in February 2023, but also conduct a second-year field day. Ultimately, we will lunch our Incubator Farm Program. **Impacts** What was accomplished under these goals? During the first year of our project, field experiments of objective 1 were completed. Data is being analyzed, while extension material is being developed, published, and shared with our clients (see publication list). Our first peer-review research publication is under development by a master's student (Austin Dorminey) under PI da Silva's supervision. Cover crop for second-year trials (Objectives 2 and 3) was acquired and will be planted within the next month. The stakeholder advisory panel is meeting in the last quarter of 2022 to discuss project results and next year's trials, also this meeting will serve to initiate our Incubator Farm for growers training, which area was prepared and activities can initiate. **Publications** - Type: Other Status: Published Year Published: 2022 Citation: da Silva, A.L.B.R., S. Oliveira, Z. Jones, S. Li. 2022. Growing organic vegetables in Alabama: Know your weeds. Alabama Cooperative Extension System. Extension Bulletin ANR-2923. - Type: Websites Status: Published Year Published: 2022 Citation: Growing organic vegetables in Alabama: Know your weeds <https://www.aces.edu/blog/topics/crop-production/growing-organic-vegetables-in-alabama-know-your-weeds/>, - Type: Other Status: Published Year Published: 2021 Citation: Majumdar, A., K. Wayne. 2021. Organic Crop Production. Extension System. Extension Bulletin ANR-2728. - Type: Other Status: Published Year Published: 2022 Citation: Majumdar, A.L.B.R. da Silva. 2022. Organic vegetable IPM toolkit. Alabama Cooperative Extension System. Factsheet.

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Assessing Soil and Plant Health Response to Composted and Solarized Grape Pomace with Manure in Semi-arid Soil

Accession No.	1027148
Project No.	ARZT-XXXXXXX-E43-500
Agency	NIFA ARZT\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2021-51106-35496
Proposal No.	2021-04807
Start Date	01 SEP 2021
Term Date	31 AUG 2024
Grant Amount	$575,000
Grant Year	2021
Investigator(s)	Mpanga, I.; Brown, JU, K..; Tronstad, RU, .; Blankinship, JO, .
Performing Institution	UNIVERSITY OF ARIZONA, 888 N EUCLID AVE, TUCSON, ARIZONA 85719-4824

NON-TECHNICAL SUMMARY

According to the United States Department of Agriculture (USDA) census data, certified organic farms in Arizona stayed identical in 2012 and 2017. Still, sales increased from \$54,503,000 to \$97,956,000, respectively (80% increase in sales), indicating high demands for organic products by Arizonans. While misconception is an issue about organic certification pricing with limited knowledge among farmers, in 2012 and 2017, 33% and 43% of the organic producers reported production as the main challenge. Arizona soils are predominantly calcareous (high above 7.5) with deficient organic matter, affecting soil nutrient cycling and availability within these irrigated desert soils, especially during the organic transition with limited alternatives for alkaline soil pH, fertility, and plant health management. Combining grape pomace (GP)) from the rapidly growing wine industries with poultry and horse manure could fill the production. Wine production in Arizona significantly increased from 65,413 gallons (2007) to 297,145 gallons (2017), with an estimated 354% increase in GP production, which unfortunately ends up in landfills. The GP has low pH (3.2 to 3.9), with 2% N, 0.5% P, 2% K, and 2% Ca per ton, making it an excellent alternative alkaline soil. Adding 5% GP to semi-arid calcareous soil reduced soil pH from 8.1 to 5.9, increased maize and wheat growth and nutrition while adding 40% poultry manure improved GP compost minerals and reduced composting time. The project proposed field application of GP to assess soil and plant health and economic profitability compared to poultry and horse manure through farmer participatory research and extension program.

OBJECTIVES

Goal: To reduce Verde Valley wineries by-products (grape pomace (GP)) as environmental waste by 100% in Arizona and instead promote it as soil and plant health enhancement alternative in semi-arid croplands in the USA and worldwide.Objectives:1. To assess the effects of composted grape pomace (CPG) and solarize grape pomace (SPG) with manure (poultry and horse) on soil health (pH, salinity, nutrient availability, organic matter, aggregate stability, water-holding capacity, water infiltration, and microbial respiration) and plant nutrient uptake efficiencies for the selected vegetable crops(carrot and spinach).2. To assess the effects of CPG and SPG combined with manure (poultry and horse) on the plant rhizosphere and phyllosphere microbial community diversity and population structure.3. To compare the economic viability and profitability of CPG and solarize SPG with manure (poultry and horse), focusing on cost, carbon credit, and crop yield.4. To promote the use of organic amendment as sustainable, regenerative agriculture soil amendment practices using extension programs and outreach with field demonstrations and field days, conference presentations, and publications.

APPROACH

The project will assess composted and solarized grape pomace (GP) effects on soil fertility, soil health, and plant (carrot and spinach) health in semi-arid croplands. The GP will be composted with poultry and horse manure at a mixture ratio of 70% GP and 30% poultry and horse manure up to one ton total weight each, respectively. The composting treatment will be; 1)100%GP 2)100%PM 3)100%HM 4)70%GP+30%PM 5)70%GP+30%HM, where GP=grape pomace, PM=poultry manure, and HM= horse manure. The material will be composted for three months with bi-weekly turning. In situ measurements will be taken during composting on temperature, moisture, pH, electrical conductivity, and mineral composition at the end of the third month. Another part of the GP will be sun-dried and pelleted with 70% GP and 30% poultry and horse manure. Field testing of the composted and solarized GP will be carried out at a USDA-certified organic farm (Agritopia Farm at 3000 East Ray Road, Gilbert, AZ, 85296) with the treatments below; 1) no fertilization 2) composted GP 3) composted PM 4) composted HM 5) Composted GP+PM 6) Composted GP+HM 7) solarized GP 8) PM 9) HM 10) solarized GP+PM 11) solarized GP+HM. The treatments will be repeated in 3 blocks with a complete randomized block design. All treatments will be applied to their specific plots as in fig 5 at N rate at 250 lbs. N/ acre/year in March and allowed a three-week window before planting in April. The project fits the plan into the farmer\'s yearly routine planting plan and dates to avoid big adjustments to existing farmer practices. Land preparation, planting, weeding, and harvesting will be done using existing on-farm practices and farmers\' equipment. Bloomsdale spinach and Wakum carrot will be planted twice every year, in February and September. Shoot sampling and analysis: Representative samples of plant shoots will be taken from each plot and crop (Blankinship\'s lab) for analysis using their commercially available protocol for macro- and micro-nutrients. Sampling for shoot analysis will be done by collecting ten plants /plot for both carrot and spinach in the middle row (a week before harvesting). The samples will be oven-dried for shoot biomass and mineral analysis. Plant shoot N will be determined by high-temperature combustion whereas B, Ca, Cu, Fe, K, Mg, Mn, Na, P, S, and Zn will be determined by ICP analysis of a nitric acid diges tand reported on a dry plant basis. Soil sampling, preparation, and analysis:Soil sampling and preparation:The soils will be sampled at 0-10 cm depth (year 1, 2, and 3) and 10-20 cm depth (year 3) with a core sampler each year at the end of each growing season (August) for analysis. The soil samples will be transported to Blankinship\'s lab for processing and analysis using the methods below that were developed for commercial analyses. Total carbon and nitrogen: This will be measured with C N elemental analyzer (Elementar Vario Max Cube).Nitrate-nitrogen (NO_3-N): The NO_3-N will be extracted with a 1 N KCl solution and determined using a 10:1 ratio (1 M KCl: \<2 mm pulverized soil) as described by Keeney and Nelson, 1982) using a microplate spectrophotometer. Other soil nutrients: Plant available P, K, Ca, Mg, Na, and S will be extracted with the Olsen method and determined using the Inductively Coupled Plasma (ICP) method (TAMU-AgriLife Extension).Orthophosphate analysis: Orthophosphate (PO_4-P) will be quantified using the colorimetric method with ascorbic acid/molybdate reagent after extraction in Mehlich-3 solution (Murphy and Riley, 1962).Micronutrients:The plant-available micronutrients (Cu, Fe, Mn, and Zn) will be extracted using a 0.005 M diethylenetriaminepentaacetic acid (DTPA) 0.01 M $CaCl_2$, and 0.10 M triethanolamine solution. Soil (20 g) will be volumetrically transferred to an extraction flask containing 40 ml of DTPA extraction solution and shaken in a 1-inch orbital unit at 180 rpm for 120 min, and passage through a Whatman #2 filter (Lindsay and Norvell, 1978), followed by inductively coupled argon plasma (ICP) analysis (http://soiltesting.tamu.edu/).Respiration measurements: Soil microbial activity and organic matter decomposability will be quantified using laboratory soil incubations under ideal temperature (25 °C) and moisture (50% of water-holding capacity). Soil samples (10 g) will be placed in airtight jars with septa. Soil CO_2concentration will be measured using an infrared gas analyzer (LI-840) after sealing each jar and then 24 h and 48 h later. Soil CO_2production rates will be calculated using linear regression.Soil physical measurements:(available water capacity, Wet aggregate stability and Dry aggregate size distribution):Ten random samples will be taken from each plot at 0 - 15 cm and composited. Samples will be air-dried in the laboratory for analyses of various soil physical measurements. The available water capacity (moisture difference between 0.03 MPa and 1.50 MPa) will be measured using the pressure plate apparatus method. Wet and dry aggregate stability (indicator of soil\'s susceptibility to soil erosion by water) will be assessed using a Cornell Sprinkle Infiltrometer and Tyler RX-29 Rotap sieve shaker, respectively. Phytomicrobiome analyses: Sampling will be carried out 1-2 weeks before harvest to capture near-real time the phytomicrobiome closely associated with peak crop health. To characterize the bacterial communities assembled in the phyllosphere (leaves, stems) and rhizosphere, respectively. The rhizosphere community is also of interest with respect to overall benefit to soil health and will be characterized in terms of treated and untreated test plants. Plant viruses will be identified by RT-PCR (RNA) or PCR (DNA) amplification using primers available for detecting plant viruses common in Arizona, followed by cloning, and Sanger sequencing. If of interest, selected positive samples may be subjected to RNAseq discovery (total RNA purification, Trizol; or Illumina DNA analysis for samples of interest (carrot or spinach).For phyllosphere community characterization, the hypervariable V4 region of the 16S rRNA gene will be amplified using a unique barcode for each sample, linked to a reverse primer (806R) and a common forward primer (515F).For the rhizosphere community composition, a shot gun metagenomic approach available from Microbiome Insights (microbiomeinsights.com/). Economics and profitability assessment of using organic amendments as a soil conditioner: A profitability assessment of GP will be made using input costs, yield data, and prices of the produce harvested from field experiments in Arizona. The methodology utilizes annual cost of production and sensitivity analyses to evaluate costs and returns over the three-year period of the trials. Observed trends over the three-year period will be extrapolated into the future, for items such as building soil organic matter from using GP with possible implications for changes in fertilizer, irrigation water, and other inputs, plus yields and output prices. Programs will be evaluated by the effectiveness of the treatments on the field and the data points obtained and also by using questions for each extension event to compare knowledge before and after, the number of farmers using grape pomace as soil, number of farmers going into organic production in Arizona. Progress 09/01/23 to 08/31/24 Outputs Target Audience:Organic vegetable producers/farmers stakeholders in southern Arizona; potentially, regenerative farms; Extension; Academia: faculty, graduate students, staff, post-docs with affiliated interests; private sector; government-state and federal; the public. Changes/Problems:Grape pomace was found to be uneconomical as a soil amendment tin the project for several reasons. First, wheat is an agronomic crop, compared to vegetable crops targeted in the initial project, making it difficult and time-consuming to apply over large areas, and required a large amount of input to cover the planting area. Second, because of the great distance between Oatman Flats (our new cooperator) and sources of pomace either in northern or southern Arizona. This treatment was therefore abandoned (envisioned by the original PI, who lived near winegrape vineyards in Yavapai Co. and arranged for the materials to be transported to Gilbert, AZ farm, initial cooperating farm). Oatman Flats Farm/Ranch had two wells at the outset of the project (Yr-2). The pump for one of these wells broke and the water distribution pipelines were damaged by flood waters, leaving the farm with one well. Experiments were completed for the 2023 cover crop and wheat crop (winter 2023-spring 2024) seasons, however, the 2024 cover crop stand was extremely poor because well water was unavailable and summer rains provided less than one inch of precipitation. Since the pandemic, it has been difficult to identify skilled workers/scientists/students interested in working on this project. Fortunately, half-way through this year, the M.S. student and Ph.D. candidate (molecular biologists, Research Technician) were hired to work on the project. The departure of two of the initial PI\'s who were soil scientists left the project without the necessary expertise. We are fortunate to have Dr. Debankur Sanyal, Soil Health Specialist, Dept. of Environmental Sciences, has agreed to join the project as a collaborator. What opportunities for training and professional development has the project provided?Training: Mr. Amir Khusru (M.S. student, UA Agric. Economics) who joined the team as a statistician is learning about plant-microbial/nutrient dynamics associated with yield. Ms. Maryum Munir, (Ph.D. candidate, Plant Pathology-Microbiology), who joined the Brown lab (Plant Sciences) as a molecular biologist is learning how to isolate nucleic acids from soil samples and prepare soil for characterization. She is learning how to analyze and interpret the physical and molecular data produced in the project. Professional development: Dr. Dinusha Maheepala, Ph.D., Plant Molecular Biology and Bioinformatics, is learning project management and coordination of the ressearch team, has developed new protocols, constructed databases, and written/optimized scripts for data analysis; he is learning new approaches and algorithms to enable microbial community analysis. How have the results been disseminated to communities of interest?Members of the farming community and other interested parties were able to attend the workshop held at the University of Arizona Cooperative Extension in Maricopa County, on May 2nd, 2024. These attendees received a thorough introduction to the benefits of using organic, soil amendments, and had an opportunity to discuss how the preliminary data from the project may be applicable to organic farmers. What do you plan to do during the next reporting period to accomplish the goals? Yield data from wheat 2025 crop (annually) Wheat grain protein analysis from 2025 crop (annuall) Cover crops biomass: the cover-crop is expected to be planted after the wheat harvest (summer 2025), which will allow biomass data to be taken this year. Algae amendments will be applied to the 2024-2025 wheat crop. Because the cover crop was not established, this soil benefit was not realized. These treatments are anticipated in 2025 growing season. Soil analysis per treatment/plot will be conducted (Dec 2024 and May 2025): Nutrient analysis. Physical and chemical properties analysis. Microbiome analyses (i.e., archaeal, bacterial). Pursue cost-effective approaches for analyzing the soil-phylosphere virome to include soil-organismal associated and phyllosphere-associated viruses. Though technically challenging, the project hopes to make some inroads into these approaches to enhance the understanding of the relationships between the interacting archaea, bacteria, and virus communities associated with soil-plant exudates. Impacts What was accomplished under these goals? Elaborated Goal (Yr-2 rescoping): In the project re-scoping, the goal is to improve soil fertility, soil health, water retention of soils, yields, quality, plant health, farm profitability, and to reduce or completely replace the costly natural chemicals or those that may have adverse effects on the environment, to reduce N and P leaching into the watershed, to provide an alternative to synthetic elemental sulfur and sulfuric acids in the organic production systems, by using algae (Chlorella spp.) and cover-cropping

(50 grass-sorghum mix:50 broadleaf) as an organic soil amendment in semi-arid croplands in the USA and worldwide. Note: This goal replaced the initial goal of reducing Verde Valley wineries by-products (grape pomace (GP)) as environmental waste by 100% in Arizona and instead promote it as soil and plant health enhancement alternative in semi-arid croplands in the USA. Elaborated/Adapted Objectives (Yr-2 rescoping): As the result of project re-scoping, the objectives addressed are: To assess the effects of algae plus cover-crop and cover-crop only treatments on soil health (pH, salinity, nutrient availability, organic matter, aggregate stability, water-holding capacity, plant-available water content, and microbial respiration). To assess the effects of algae plus cover-crop and cover-crop only treatments on the plant rhizosphere microbial (i.e., bacterial and archaean) community diversity and population structure. To compare the economic viability and profitability of algae plus cover-crop and cover-crop only treatments, focusing on cost, carbon credit, and crop yield. To promote the use of organic amendments \sheep manure/grazing farm-wide, algae products, and cover crop after the commercial crop is harvested\, as sustainable, regenerative agriculture soil amendment practices using extension programs and outreach with field demonstrations and field days, conference presentations, and publications. Soil Treatments: Algae + cover-crop and cover-crop only treatments were applied to wheat crop. Algae was the choice for organic amendment. Data collected for analysis of the organic amendments effects: 1. Yield for Sonoran wheat plots (commercial product) 2. Wheat grain for protein analyses. 3. Soil analysis per treatment/plot: Soil physical and chemical properties Soil nutrients Microbiome community diversity and abundance (archaea, bacteria and virome). 4. Results of data analysis, correlations, and trends produced for the study at Oatman Flats Farm (Organic and regenerative practices) (Appendix II is available): Soil nutrients Soil physical and chemical properties Soil water nutrients Cover-crop biomass Wheat grain weight Wheat grain protein content Soil bacterial and archaean diversity Impacts: According to the United States Department of Agriculture (USDA) census data, certified organic farms in Arizona stayed identical in 2012 and 2017. Still, sales increased from \$54,503,000 to \$97,956,000, respectively (80% increase in sales), indicating high demands for organic products by Arizonans. While misconception is an issue about organic certification pricing with limited knowledge among farmers, in 2012 and 2017, 33% and 43% of the organic producers reported production as the main challenge. Arizona soils are predominantly calcareous (high above 7.5) with deficient organic matter, affecting soil nutrient cycling and availability within these irrigated desert soils, especially during the organic transition with limited alternatives for alkaline soil pH, fertility, and plant health management. Combining organic amendments such as algae and cover-crops is anticipated to fill at least some of the need for alternative organic amendments to improve soil health and harvest and lessen the use of inorganic fertilizers that contribute to cost, salt accumulation, and run-off in water. Algae may cost less than traditional fertilizers and become more cost-effective to culture on site. The prices vary substantially with the specific product/algae type, formulation, and supplier. Once applied to soil, algae decompose readily, providing a rich nutrient source for microbial life that enhance plant-available soil nutrients and reduce the potential for plant disease. The benefits of algal amendments are not well documented but there is much optimism about their use as organic amendments to improve soil structure and nourish soil-associated eukaryotes, invertebrates, and prokaryotic microbial communities. Numerous cover-crop seed mixes are widely available. Planting cover crops (dicot-monocot mix) after the wheat harvest in arid fields, such as those that typify Oatman Flats ranch, with minimal water supply, and once established, provided space for the microbiome community to thrive and a refuge for beneficial insects such as ladybugs, predators, and parasitoids, and had the effect of reducing soil erosion and the appearances of improved structure (easier to dig, more moisture retention), potentially enabling crop roots reach the depths needed for nutrient and water uptake. Improvements to available phosphorus and soil microbial communities that improve plant-available nitrogen content are already noticeable in the data (please see Appendix II for further details). This is the second year to treatment applications at the participating farm, which grows Heirloom Sonoran whitefly wheat (Oatman Flats Ranch, Gila Bend, AZ). Grain yield and protein content of grain data are available for the current year and should be collected for at least one more year before robust conclusions can be drawn with respect to the effectiveness of the algae and cover-crop organic soil amendments. The cost of purchasing/hauling and applying grape pomace to Oatman Flats farm was evaluated in the context of the new participating farm (Gila Bend, AZ) (replaced original partner in Gilbert AZ) that pulled out of the project due to pandemic-related constraints). The distance, cost of truck rental, fuel, and time-consuming compositing made this treatment untenable for an agronomic crop such as wheat. Algal amendments were therefore selected as more tractable option together with cover crop, and manure provided by sheep that graze on the property (wheat stubble, Bermuda grass (weedy; previous recommended practice implemented for erosion control) and the mix monocot-dicot cover crop. Other economic benefits have not been evaluated given this is the first year for which data are available with respect to wheat yield/quality, soil characteristic\'s post-treatment, and the soil/microbial community profiles. Publications Type: Theses/Dissertations Status: Published Year Published: 2024 Citation: Economics of Grape Pomace, Poultry Manure and Horse Manure as Soil Amendments.\" Masters thesis, The University of Arizona. https://www.proquest.com/openview/b9b55c38f1a1f58057ec42245aaccd43/1?pq-origsite=gscholar&cbl=18750&diss=y Progress 09/01/22 to 08/31/23 Outputs Target Audience:Organic vegetable producers and farmers, Maricopa/Pima County vicinities Extension personnel Students, staff, and post-

docs/professionals in the labs (Plant Sciences, Agric. Economics) Changes/Problems:Our collaborators at Agritopia Farm in Gilbert Arizona have become overwhelmed (post-CoVID associated problems, difficult to hire help, extreme summer temperatures and drought conditions under which a quality experimental plot can be established and maintained) and have requested to leave the project, regrettably. Further, one co-PI, Dr. J. Blankenship (soil sciences) has stepped off the project due to personal/family considerations during and post-coVID. We propose to move the research to a different location and have identified an alternate organic (and regenerative agriculture) farm, Oatman Flats (near Gila Bend), that farms wheat/cover crop rotation and algal amendments to improve soil and plant health. The manager Dr. Yadi Wang is excited about establishing a fruitful collaboration and is a trustworthy collaborator and an excellent soil physicist/chemist/farmer. In addition, Dr. Debankur Sanyal (UA Soil Scientist, Extension, UA Maricopa Agric Center) will join the project as Collaborator in lieu of this expertise in soil sciences expert & organic farming. We propose a one no-cost extension next year to permit 2 years of data to be collected (Aug 2023-Aug 31, 2025). There are sufficient funds remaining to conduct the proposed study, particularly given the slow start at Agritopia due to covid-related issues on that affected the UA team as well as the Agritopia partner (restricted campus/lab access and hiring during 2020-2022. The proposed re-scoped workplan for the cropping system and analyses are briefly summarized below. Cropping System: Soil and plant health -organic practices wheat/cover crop plus algae soil amendment with our without sheep manure Soil analyses Standard-plus parameters Microbiome analysis-soil/root exudate region (Bacteria; Archaebacteria-extremophiles PACBIO 16S v1-9 region) Water analysis In-ground collection w sensor/collector, instead of characteristic sampling of irrigation water to uncover the water composition when interacting with soil; Traditional chemistry analysis (Phx laboratory) compared to more detailed and concise parameters obtained using the Henne method (outsource to Nebraska lab). Phx lab does not conduct Henne analysis. Plant sample analysis Above ground - petiole analysis -in plantavs soil Above ground: crown - wheat plant microbiome (if cost permits) - nutritional value Biomass - transects for cover crop and wheat Soil Amendments Algal amendment to fortify bacterial community. Cover crop 50 grass-sorghum mix:50 broadleaf Sheep manure Note: The Agritopia plan considered manure amendments and composted grape pomace in vegetable crops. Pomace is not a good option for agronomic crops and sheep manure is already a component of the farming practice. Even if desireable and sufficiently plentiful, pomace is only affordable when produced on the farm (cost of hauling pomace from Wilcox, the nearest sources, is prohibitive). What opportunities for training and professional development has the project provided?Post-doctoral Associate received one year of training in plant sciences/soil sciences/microbiome analysis June 2022-2023 before leaving for permanent position in the chemical industry. M.S. graduate student is receiving training in agriculture economics. Post-doc optimized microbiome analysis and trained laboratory technician in soil extraction, DNA isolation, and preparation for sequencing. How have the results been disseminated to communities of interest? Participating farm, on which results of improved crop performance from application of soil amendments can be scaled to other fields on rest of farm. The vineyards from which the grape pomace is sourced get relief from managing the pomace as waste. Other farmers, especially certified organic farms, in determining the best manure to use for amending soils. What do you plan to do during the next reporting period to accomplish the goals?PLANS recorded for Agritopia until the Farm Manager notified us Agritopia could not continue to collaborate because they are overwhelmed due to personnel shortage, high summer-fall heat conditions, and request for our team to help far more than we are able to do. Plant and measure yield and quality differences for crops planted this fall and next spring. In addition, investigate how soil sampling data overlays with yield and quality responses observed. Add more data to a similar multiple regression model used above to quantify the yield differences between soil treatments depending on the % mix of grape pomace, horse manure, poultry manure, and whether composted or not. Evaluate the multi-year costs and benefits associated with the different soil treatments with more yield and quality data. Additional workshops and field visits are planned that will give famers an opportunity to visit the research field and observe the experiments, as well as have discussions and seminars on the topic that are important for soil health managements. Publications or bulletins with information and results from this research will be produced and disseminated as more data is collected ana analyzed which will add to the knowledge and literature available on soil health and management. Please see the next section regarding problems and the proposed re-scoping of the project to work with an organic, regenerative farm Oatman Flats (near Gila Bend) to employ similar but revised practices/amendments, and innovative soil, rhizosphere, and water analysis. A zoom call was held with the Program Directors (late July) to discuss the proposed revised scope. Details will follow in the next section. The team would like in advance to request a one-year no-cost extension to facilitate the collection of field data through August 2025 (2023-2025) and finalize publications. No modifications to the budget are requested. One co-PI, Dr. J. Blankenship (soil sciences) has stepped off the project due to personal/family considerations during and post-coVID. Dr. Debankur (UA Maricopa Agric Center) will step in as Collaborator and soil sciences expert & organic farming expert. Work has already been initiated to sample and analyze soil rhizosphere and water to establish baseline values. The cover crop and amendments have been established as the seasonal regenerative practice to precede planting the wheat crop, late fall-early winter. A memo: Request for changes will be submitted shortly to UA Sponsored Projects-Vice President for Research for approval, and forwarded to USDA-NIFA Program Managers. Impacts What was accomplished under these goals? Obj. 1. Maturity and harvest data indicated non-uniformity of field performance beyond effect of treatments, requiring re-location of plots. A composite soil sample was collected for each treatment across replications and mineral and nutrient analysis were carried out. Results showed divergence for treatments from baseline. Comparisons across treatments and heatmaps using normalized data were produced, indicating a decrease in soil pH for most treatments compared to the control. Completed growing season of cabbage crop (fall, winter) in the new (re-located) plot and collected data. Post-cabbage (fall, winter) harvest, spaghetti squash #1 was planted (early April); harvest data were collected, and treatments compared; soil samples were analyzed for chemical indicators. Spaghetti squash crop #2 was planted late May 2023; record-high temperatures prevented normal growth; crops were abandoned Aug 2023. Composting pomace and application of soil treatments were planned for September cropping cycle (#2, relocated plot). Conclusions: Preliminary analysis indicated that grape pomace has potential to reduce soil pH when applied to high pH soils; significant differences exist among treatment effects, but conclusive inferences cannot be drawn from a single season of data. More data from multiple seasons and years are needed to draw accurate conclusions from which recommendations can be based for managing soil health using grape pomace and manure. Impacts: Demonstrated difference in effects of different organic soil amendments on crop production/health. Preliminary results indicated significant difference in yield from plots with different treatments, with composted grape pomace treatment producing significantly higher yield (total cabbage weight), compared to the controls; Soil test results have also indicated a substantial decrease in soil pH after just one growing season. Reduction in soil pH is among the primary objectives of this research that seeks to exploit the low pH levels in grape pomace as a soil amendment in organic crop systems. Obj. 2. The effects of grape pomace and manures on soil microbial diversity and population to ascertain the concomitant effect of soil health for improved production in a certified organic production system. Samples were collected from cabbage root, shoots and rhizosphere soils for analyses, including microbial composition. Preliminary sequencing results revealed an overwhelming proportion of mitochondrial and chloroplast DNA that interferred with characterization of microbial composition based on 16S rRNA gene sequences. A protocol was designed and optimized to include peptide nucleic acid (PNA) clamps to prevent amplification of mitochondrial and chloroplast DNA, while targeting 16S rDNA of the bacterial/archaeabacterial community. Results showed plastid 16S rRNA sequences (reads) were nearly entirely eliminated, facilitating optimal coverage of true Bacteria and Archaebacteria 16S rDNA sequences (OTUs). Conclusions: Soil analyses aided in interpreting crop responses to some extent. The optimized PNA Clamp method proved effective for removing interferring plastid 16S rDNA sequences. Impacts: Competence and proficiency in handling and analysis of parameters of microbiome assays has been developed in our lab group. A protocol and pipeline to analyze soil and plant microbiome data is in place for future experiments. Obj. 3. Horse manure is a commonly used soil amendment in AZ small and limited-resource operations because horse owners haul at no charge to nearby farms in need. With horse manure use, organic matter increases but EC and phosphorous levels increase to potentially detrimental levels; thus proposed amendments have potential to mitigate some of these adverse impacts. Cabbage yield (lbs.) and a quality measure of size (cm) were recorded for 11 soil treatments and negative control for February 2023 harvest. A heat map of marketable, unmarketable, and total yield (lbs) for each soil treatment was carried out for the random design with three replicates per treatment. To determine if statistically significant differences occurred between composting and other test materials, a multiple regression analysis was conducted using the equation: ?????? = ??0 + ??1DC + ??2GP +??3HM + ??4PM ?????? = Yield or weight in lbs of cabbage (marketable & unmarketable) weighed by treatment (11) and replication (3) DC = Dummy for Composted (1 if composted treatment, 0 otherwise) GP = Percent of Grape Pomace in Treatment HM = Percent of Horse Manure in Treatment PM = Percent of Poultry Manure in Treatment While results are from one crop and year, the highest yielding treatments were the untreated control and grape pomace replicates. Treatments that received only poultry or horse manure, composted or solarized had statistically lower yields (5% significance) compared to grape pomace or no treatment. Composting was insignificant relative to solarized/dried pomace. Several factors related to uneven drip irrigation confounded quantification of economic value of pomace treatments, compared to no-treatment controls. Because time is required for soil treatments to influence the soil chracteristics, economic conclusions cannot be drawn until additional results of yield,quality, and water holding capacity are available. Conclusions: Continued collection of yield and quality measures of vegetable crops grown with different soil treatments are needed to evaluate longer term differences in economic returns among treatments; soil water holding capacity will be added to the soil measurements taken determine how much water may be saved from different soil treatments for different plots and points in time. Impacts: Although yields were higher for the control of no soil amendment and grape pomace than horse manure, in particular, more crops and years are needed to confirm this result. Sourcing pomace is costly compared to the horse manure that is delivered free to the farm. free. The most economically profitable solution is to not apply any amendments based on this first year of results. The economic returns will be determined for different soil amendments in the subsequent season to quantify how the different soil amendments of grape pomace, horse manure, and poultry manure affect fertility, yield, and profitability of high value organic produce crops. 4. Research results from this experiment and lessons learned along the way will be beneficial to a wider community of farmers, both certified organic and non-organic producers, in the efforts to manage soil health. The goal is to sensitize and disseminate information regarding grape pomace and manures as soil amendments to manage soil health. A workshop was organized and facilitated at Agritopia farm premises on May 8th, 2023, attended by \>30 growers interested in soil health and management in organic cropping systems. Presentations were given by speakers from the University of Arizona including Drs. Russell Tronstad, Herbert Sserunkuma, and Joseph Blankinship. The Farm Manager and PI\'s led the field tour and the manager led the farmer-to-farmer discussion session. Two scientific articles reporting supporting data on use of soil pomace from studies carried out prior to and after project initiation, were published in a peer reviewed scientific journals. Conclusions: There is great interest from communities to learn about research and new findings on soil health and management; Workshops and seminars are effective ways to engage farmers and disseminate research information; Farmers have an interest in knowledge regarding soil health management, most of whom rely on information from fellow farmers or practices used traditionally in their communities. Impacts: Attendees expressed appreciation for the program information, availability of resources from presenters and Farm manager, and were eager to learn of new opportunities for funding/collaborations that could benefit them and their operations. Publications Type: Journal Articles Status: Published Year Published: 2023 Citation: Mpanga, I. Neumann, G., Brown, J.K., Blankinship, J., Tronstad, R. and Odowu, J.O. 2023. Grape pomaces potential on semi-arid soil health enhance performance of maize, wheat, and grape crops. J. Plant Nutr. Soil Sci. 2023; 1-10. doi:10.1002/jpln.202200232. Type: Journal Articles Status: Published Year Published: 2022 Citation: Mpanga, I. K., Sserunkuma, H., Tronstad, R., Pierce, M., & Brown, J. K. (2022). Soil Health Assessment of Three Semi-Arid Soil Textures in an Arizona Vineyard Irrigated with Reclaimed Municipal Water. Water, 14(18), Article 18. https://doi.org/10.3390/w14182922. **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience: Small farms, producer that market locally and through public farmers market, and limited resource producers Changes/Problems: In the first planting, seeding was not uniform and drip irrigation lines were not attended to regularly, resulting in an uneven stand. This prevented meaningful yield data from being taken. All the other data collections proposed, however, were obtained and analyses are either completed or underway for the first crop, spinach. To address the issue of nonuniform plant populations, a more level plot of ground has been identified so that the drip irrigation water doesn't pool up and flood some low areas \-- resulting in nonuniform stand populations. What opportunities for training and professional development has the project provided? One post-doc is training in soil sciences to conduct hands-on soil and water analysis lab, and in plant sciences lab / to learn molecular techniques and methods (DNA isolation, PCR amplification, cloning, gel electrophoresis, sterile technique, other) required for microbiome analysis. She has participated in lab meetings and field visits, is coordinating the research at the field site, and has carried out literature review relevant to the project objectives. An M.S. student is being trained in Agriculture Economics and has completed most of her course work in the first two semesters. She has also participated in lab meetings and field visits, and carried out literature review relevant to the project objectives. An M.S. student has arrived to the microbiology lab partner, Fall semester 2022 and will be involved in the microbiome/virome objective. How have the results been disseminated to communities of interest? Four in-person meetings have been held between our team and the farm manager, and results have been discussed, as well as modifications to procedures for more optimal, uniform crop stands and irrigation in the summer crop, which spaghetti squash. At harvest though the stand was more uniform than spinach (Spring 2022), the decision was made to relocate the experimental plot to the middle of another field, re-sample the soil after leveling, and plant cabbage transplants as the fall crop. Drip irrigation + amendments as planned will be set after transplanting the first week of October. What do you plan to do during the next reporting period to accomplish the goals?The spaghetti squash has been planted and bi-weekly visits to the farm are planned to help oversee the crop and assist with weed control and other maintenance, as needed. Sampling will be carried out at the end of the season for plant nutrients, yield, and soil analysis. Samples from spinach and squash crops will be processed for microbiome analysis, and soil samples will be prepared for microbial analysis. Preparations will be made to plant the fall crop, which will be transplanted cabbage, followed by green beans (Spring 2023). Amendments including manure and grape pomace will be procured to begin composting in October for the 2023 season. At least one manuscript reporting preliminary data for GP experiments carried out in field and greenhouse settings (the project was getting underway in 2021), will be submitted for review in a peer reviewed journal. **Impacts** What was accomplished under these goals? Materials for solarizing or composting grape pomace were assembled; composting was carried out for grape pomace, chicken manure, and cow manure during Oct-Dec 2021. Experimental plots were established in January 2022 (spinach) with eleven different treatments, including no fertlizer control; random design, 3 replicates each. At the end of the cropping season, spinach plants were sampled and prepared for nutrient analysis; a subset of leaves were frozen for microbiome analysis. At the end of the cropping season, soil was collected and analyzed for pH, nitrogen, and other elements nutrients and frozen for at the microbiome analysis. Given the experimental nature of grape pomace (first time on this site), it was important to learn that foliar nutrients in spinach leaves (P, Ca, Fe, B, Cu, and Mn) were not significantly affected by soil amendment addition. Composted poultry manure addition would benefit crop quality by increasing plant nutrient uptake. Solarized grape pomace can be used as an organic soil amendment for soil pH and fertility management in arid regions. Additional crops, cropping cycles, and replicated studies are needed to determine if long term benefits will be achieved and how the treatments influence the microbial community/virome and plant health interactions. Some yield data were collected, although problems in stand consistency of crop make the yield and resulting economic evaluations suspect. To address the inconsistency of establishing each crop, a more level plot of land has been identified to make comparisons among different treatments much more reliable and meaningful to the economic viabiity and profitability of different soil treatments. The fall plot (re-located to middle of the field and leveled) will be transplanted to the cabbage crop, with the same treatments as in the initial workplan (pomace, manures, etc). **Publications** - Type: Other Status: Other Year Published: 2022 Citation: Soil health management in arid environments. Presentations on soil health were given by the post-doc (Dr. P. Sharma) at two Beginning Farmers workshops.

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Cereal-pea Intercropping Systems as a Profitable Cropping Strategy to Organic Transitions and Soil Health

Accession No.	1027092
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Performing Institution	UNIV OF IDAHO, 875 PERIMETER DRIVE, MOSCOW, IDAHO 83844-9803

NON-TECHNICAL SUMMARY

Agronomic tools are needed to facilitate the transition from conventional to organic farming. The long-term goal of our project is to develop cereal-pulse intercropping systems under low water availabilities for enhancing agroecosystem sustainability and productivity during the transition to organic farming and thereafter. A three-year field experiment during organic transition and trials on grower-collaborator organic farms will improve our understanding of the effects of cereal-pea intercropping systems on crop productivity, soil health and fertility, greenhouse gas mitigation, and enhanced diversity of crops and soil microbes under well-watered and drought-stressed conditions. The results will provide direct evidence of the effectiveness of cereal-pea intercropping systems to supply a substantial source of biologically fixed nitrogen, mitigate nitrous oxide and methane gas flux, and increase crop and microbial diversity. Such results are presently sparse in the peer-reviewed literature. Net returns and profit risk profiles for each cropping system will be estimated using field-level input usage and yield data as well as market prices. Findings from the project will be transferred to stakeholders and the public through publications, an intercropping website, workshops, on-farm field days, and presentations at other extension events. Growers from other regions will be invited to attend annual workshops and meetings with a focus on intercropping systems, after which they can act as advisors or consultants in their own regions. To educate next-generation scientists, undergraduate and graduate students will be recruited, and project results will be included in university coursework and introduced to middle-school agricultural teachers for their curriculum.

OBJECTIVES

The long-term goal of our project is to develop cereal-pulse intercropping systems under low water availabilities for enhancing agroecosystem sustainability and productivity during organic transition and in subsequent organic farming. Specific objectives are:Objective 1. Understand the effects of cereal-pea intercropping systems on crop productivity, soil health and fertility, and enhanced diversity of crops and soil microbes under well-watered and drought-stressed conditions during organic transition.Objective 2 Involve undergraduate and graduate students in working on the project and include the project in course materials.Objective 3 Determine the overall economic return of intercropping production under irrigated and dryland conditions during organic transition and on organic farms and transfer findings from the project to stakeholders and the public via a robust extension and outreach plan.

APPROACH

A three-year field experiment will be conducted at the Aberdeen Research & Extension Center, University of Idaho in a field that meets the requirements for organic transition certification. We will establish experimental plots of monoculture and intercropping spring wheat, spring barley, and spring pea under two water regimes. The two water regimes will consist of well-watered and drought-stressed conditions. The experiment will follow a two-factor split-plot design with four replicates and will be repeated for three years. To create intercropping systems, spring wheat (or barley) and spring pea will be planted in alternate rows at four seeding rate compositions, besides the monocropping treatment of each crop. All crops will be planted in mid to late April and harvested in August. During each growing season, no fertilizers will be applied to intercropping plots and organic nutrient products will be applied to monoculture plots based on the pre-planting soil nutrient test. To create the two water regimes, irrigation will be applied at 100 (well-watered) and 50% (drought-stressed) of crop evapotranspiration (ETc). ETc will be calculated by multiplying reference evapotranspiration (ETo) by crop coefficients (Kc) of spring pea and spring grain. Soil moisture will be monitored using a soil moisture probe to quantify soil moisture dynamics throughout each growing season.The date of each crop growth stage in individual plots will be recorded during each growing season. To evaluate crop canopy development, leaf area index and normalized difference vegetation index will be measured at each growth stage. To evaluate the capability of suppressing weed growth in intercropping systems, weed samples will be collected from each plot when the canopy closes. Weeds will be quantified by species and dried for dry matter. Plant aboveground biomass will be sampled in the middle of each plot at the heading stage and physiological maturity of spring grain. Samples collected at physiological maturity will be used to estimate yield component parameters. Biomass samples will be separated into vegetative tissues (leaf and stem) and spikes (cereals) or pods (spring pea), and then dried for dry matter. Representative samples of vegetative tissues collected at physiological maturity will be ground and analyzed for forage nutrients. At physiological maturity, all plots will be harvested using a small-plot combine. Water use efficiency and land equivalent ratio will be calculated in each plot. The harvested wheat grain will be analyzed for end-use quality.Soil samples will be taken in 15 cm increments to a depth of 90 cm during the heading stage of cereals. Roots from each depth will be collected. The roots will be scanned for root length, surface area, and diameter. After measurement for morphological parameters, roots will be dried for dry matter.Soil samples will be taken at 0-15 and 15-30 cm soil depths at planting and harvest. The plant and soil samples will be analyzed for concentrations of C, N, 13C, and 15N to quantify C and N allocation in plants and soil C and N accumulation. Leaves will be sampled during the tillering, stem extension, and boot stages, oven dried, then ground for isotopic analysis (13C and 18O). Photosynthetic 13C discrimination will be calculated. Nutrient concentrations (ammonia and nitrate) of rhizosphere and soil samples will be quantitatively analyzed to assess nutrient availability in the soil and N leaching. Microbial biomass will be extracted from the soil at the 0-15 and 15-30 cm depths. Phospholipid fatty acids will be extracted from the 0-15 cm depths to provides information about the general microbial groups present.We will also measure the soil gas flux of CO2, CH4, and N2O, bi-monthly over the growing season to estimate cumulative values between treatments. On-farm trials will be conducted on three producer collaborators\' organic farms during the 3rd and 4th years of the project when promising practices of intercropping systems are identified from the first two years of the field experiment. The three organic growers are located in south and south-central Idaho. Two of them have irrigation on their farms and the other one has dryland cropland. Growers will use their equipment for planting and harvest and follow their typical irrigation scheduling on irrigated farms. Production costs (e.g., labor, equipment adjustment and modification, irrigation, and seeding cleaning, etc.) will be recorded. Soil samples and samples for crop yield and biomass will be taken from the intercropping fields, as well as the monoculture fields on the rest of the producers\' farms to serve as a control for each site. The sample analyses will be the same as the field experiment at Aberdeen. Yield will also be recorded from the yield monitoring systems of growers\' combines.The economic analysis will be primarily composed of a comparison of profitability of the various types of monoculture versus cereal-pea production systems. The approach will be based on that from a similar study developed by Chavas et al. (2009) in which each cropping system has an associated net return (difference between sales revenues and government payments and operating costs) and risk premium that accounts for variability in net returns associated with changes in key variables such as yields and prices. The results from the economic analysis are expected to enhance the knowledge available to producers for improved decision-making on intercropping production, and therefore also be of interest to extension personnel and other stakeholders in the public and private sectors. The results of this project will be prepared for peer-refereed publications and distilled into peer-reviewed extension articles and trade-journal articles. These publications will be available online, and handouts will also be printed and distributed to producers at field days and other outreach events. The creation of a website will allow producers, partners, researchers, and the public to access information anytime, anywhere. We will use this website to share the aims of the project, and our progress with quarterly updates. The website will include text, video, and audio content. Undergraduate and graduate students will be recruited to work on the project. The project will be introduced to agricultural teachers of pre K-12th grade through visits to our field and labs and as materials and resources for the curriculum. The project will also be incorporated into teaching materials for undergraduate and graduate courses at the University of Idaho. A formative evaluation to monitor the program outcomes will be conducted annually. We will conduct a summative assessment after the completion of the project to develop a final progress report. We will use qualitative, quantitative, and mixed methods to measure project outcomes, success, and challenges .To measure short-term outcomes, pre and post-tests and retrospective surveys will be administered. The video watched and downloads of publications will serve as proxy measures of awareness, knowledge, and audiences\' intention-to-adopt intercropping practices. The follow-up evaluations will be conducted at the end of each cropping year to measure the medium-term outcomes, including changes in cereal-pulse intercropping practices, their adoptions, and farm profitability. The long-term impacts of the project will be measured at the end of the project by using surveys, focus groups, and in-depth individual interviews. Additional surveys will be conducted using web-based outreach efforts. Progress 09/01/23 to 08/31/24 Outputs Target Audience:We demonstrated our project at multiple events, and target audiences include growers, crop consultants, industry agronomists, representatives of commodity groups (i.e., Idaho Barley Commission and Idaho Wheat Commission), graduate students, researchers, and the general public. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?3 Ph.D. students are working on agronomy, crop ecophysiology, and soil health as their dissertation projects. 1 undergraduate worked with Ph.D. students and PIs to assist with plant and soil sample collection and processing (e.g., sample grinding). 2 high-school students worked with Ph.D. students and PI to assist with experiment preparation (e.g., seedpacking for planting) and plant sample collection and processing for biomass accumulation and partitioning, grain quality, yieldcomponents, etc. How have the results been disseminated to communities of interest?We demonstrated our project at 8 events below: Cereal-pea intercropping systems under different water regimes in organic farming. Aberdeen Potato IPM Field Day, Aberdeen, ID. August 22, 2024; Cropping system diversity. Aberdeen Twilight Tour, Aberdeen, ID. July 17, 2024; Cereal-pea intercropping systems as a profitable cropping strategy to organic transitions. Rupert Field day, July 10, 2024; Aberdeen Field Day, July 16, 2024; Tetonia Field Day, July 25, 2024. (3 presentations); Soil Health when Transitioning to Organic Production: Practices and Metrics. Kimberly R&E Center Weed Tour.June 26, 2024. Kimberly, ID; Cereal-pea intercropping systems under different water regimes in organic farming. Western Wheat Work Field Tour, Aberdeen, ID. June 18, 2024 (invited). IAMP Project Overview. Regen Ag Workshop.November 15, 2023. Twin Falls, ID.This intercropping project was highlighted and data from this study was presented due to the stakeholders present The pea intercropping practices in this project have been considered sustainable and incorporated into two projects funded by NRCS: Climate-Smart Commodities for Idaho: A Public-Private-Tribal Partnership. USDA-NRCS Partnerships for Climate-Smart Commodities. Total \$55M(2023-2028). (also called Innovative Agriculture and Marketing Partnership, IAMP) Expanding the STAR Program across Colorado and the West. USDA-NRCS Partnerships for Climate-Smart Commodities. Total \$25M (2023-2028). What do you plan to do during the next reporting period to accomplish the goals?We will finish the sample processing from the field experiment. With 3-year data (2022-2024) (especially crop yield and quality), we will be more confident in recommending intercropping practices to growers. We will continue to work with organic growers for on-farm trials of intercropping practices in southern Idaho. For economic analyses, we will gather updated data on barley, wheat, and pea prices and fertilizer prices (both conventionaland organic), from which production costs for each treatment in 2022-2024will be estimated. We will evaluate themarketability of produced barley, peas, and wheat, including details on the local market structure, yield variability functionsbased on field data for 2022-2024and price (grains/peas, fertilizer) variability functions based on 5-year historical data, economic returns analysis for each treatment that accounts for variability in yields, grain/pea prices, fertilizer prices. Impacts What was accomplished under these goals? Crop producers need robust agronomic tools to achieve high productivity with limitedwater availability while sustaining limited soil resources in organic farming. This project adds to this toolset by focusing on producer-relevant response variables such as crop yield and quality, water use, soil fertility and health, and farming profitability for organic production systems of cereal-pea intercropping. This project also intensifies and diversifies cropping systems for crops critical to Idaho\'s and the region\'s economy. Results from this project will highlight the benefits of an organic production system that increases overall crop productivity, enhances soil fertility and health, and improves crop resilience to drought stress, by adding structural and functional diversities to agroecosystems. Objective 1: Understand the effects of cereal-pea intercropping systems on crop productivity, soil health and fertility, and enhanced diversity of crops and soil microbes under well-watered and drought-stressed conditions during the organic transition. The third-year field experiment was successfully established and harvested as we proposed. Plant and soil samples have been collectedfor crop growth and productivity as well as soil health and fertility for 2024 and are being processed. Soil greenhouse gasemissions were measured during the 2024 growing season. Wheat grain yield of 2023 was not affected by cropping systems or water regimes. There were slight differences in barley grain yield in 2023: 75%barly+50%pea under well-watered conditions produced greater yield than 75%barley+75%pea under well-watered conditions and monocropping barley under drought stress. These results are very different from grain yields in the first year (2022).It could be due to the soil residual nutrients from oat green manures in 2020 and 2021 have been depleted in the second growing season. We are looking forwardto results from the third year with more soil nutrient depletion in monocropping treatments, and intercropping treatments ofhigh pea stands may exhibit superiority to monocropping cereals. Whole-plant biomass nutritive values of 2022 were greatly impacted by cropping systems. Cropping systems with high pea stands (e.g., monocropping peas) had greater crude protein concentrations in the biomass, whereas cropping systems with high stands of small grains (e.g., monocropping wheat and barley) had greater fiber concentrations. Objective 2: Involve undergraduate and graduate students in working on the project and include the project in course materials. We have involved 1 undergraduate and 3 Ph.D. students working on this project. Objective 3: Determine the overall economic return of intercropping production under irrigated and dryland conditions during organic transition and on organic farms and transfer findings from the project to stakeholders and the public via a robust extension and outreach plan. Some project information has been added to theproposed webpage(https://www.croppingsystems.org/), and more information will be updated this fall. We demonstrated our project to stakeholders and the public at 8 events.A workshop was hosted during the Magic Valley Soil Health Forum to discuss intercropping practices on February 12, 2024. Attended producers talked about their implementation of pea-small grain and alfalfa-grass intercropping. Discussion afterward generated some interest in cereal-pea intercropping.Participants of our extension events have become more aware of the option of cereal-peaintercropping systems, especially in organic transition and organic farming. Three on-farm trials were implemented for intercropping pulses and small grains in Fairfield, Shoshone, and Twin Falls in southern Idaho. Each utilized fields with low water inputs and low soil fertility values. The producer in Twin Falls had 2 T/A yields of feed barley + pea, which will replace grazable alfalfa as fall forage for his cows. The other two producers had poor stands due to a late frost in June. Publications Type: Other Status: Published Year Published: 2023 Citation: Liang, X., Z. Kayler, L. Schott, P. Hatenzbuehler, N. Ghimire. Cereal-pea intercropping systems under different water regimes during the organic transition. ASA-CSSA-SSSA Annual Meetings. St. Louis, MO, October 29-November 1, 2023. Progress 09/01/22 to 08/31/23 Outputs Target Audience:We demonstrated our project at multiple events, and target audiences include growers, crop consultants, industry agronomists, representatives of commodity groups (i.e., Idaho Barley Commission and Idaho Wheat Commission), graduate students, researchers, and the general public. Changes/Problems:We collected soil cores/root samples from 6 depths: 0-6, 6-12, 12-18, 18-24, 24-30, and 30-36 inches in 2022as we proposed in the proposal.When processing the root samples, we noticed thatthere was almost no root at 30-36 inches. We contacted the program leader to confirm that root samples at 30-36 inches are not critical. So root sampling at 30-36 inches was excluded in 2023. What opportunities for training and professional development has the project provided?3Ph.D. students have been recruited to work on agronomy,crop ecophysiology, and soil health as their dissertation projects. 1 undergraduate worked with Ph.D. students and PIs to assist with plant and soil sample collection andprocessing (e.g., sample grinding). 2 high-school students have been working with Ph.D. studentsand PIto assist with experiment preparation (e.g., seed packing for planting)and plant sample collection andprocessing for biomass accumulation and partitioning, grain quality, yield components, etc. How have the results been disseminated to communities of interest?We demonstrated our project at 11events below: Cereal intercropping systems under well-watered and drought-stressed conditions. Aberdeen Potato IPM field day. August 16, 2023. Cereal intercropping systems under well-watered and drought-stressed conditions. Rupert Field Day, July 11, 2023; Idaho Falls Field Day, July 19, 2023; Aberdeen Field Day, July 20, 2023; Soda Springs Field Day, July 25, 2023; Tetonia Field Day, July 25, 2023. (5 presentations) Cereal-pea intercropping systems in organic farming. UI Pest Management Research Tours, Kimberly, ID, June 28, 2023. Cereal intercropping systems under well-watered and drought-stressed conditions. UI Pest Management Research Tours, Aberdeen, ID, June 27, 2023. Cereal-pea intercropping systems as a profitable cropping strategy to organic transitions and soil health. Magic Valley Organic Field Day, Buhl, ID, June 13, 2023. Cereal intercropping systems under well-watered and drought-stressed conditions. Wheat Field Day. Hermiston, OR, June 12, 2023. (invited) Cereal-pea intercropping systems as a profitable cropping strategy to organic transitions and soil health. USDA NIFA: OREI & ORG Project Directors Meeting. Washington, D.C., April 19-20, 2023. What do you plan to do during the next reporting period to accomplish the goals?We will continue our field experiment for the third year. With 2-year data (2022-2023) (especially crop yield and quality),we will be more confident in recommending intercropping practices to growers in 2024. We will work with 3 organic growers for on-farm trials of intercropping practices in southern Idaho. For economic analyses, we will gather updated data on barley, wheat, and pea prices and fertilizer prices(both conventional and organic), from which production costs for each treatment in 2022 and 2023 will be estimated. We will evaluate the marketability of produced barley, peas, and wheat, including details on the local market structure,yield variability functions based on field data for 2022 and 2023 and price (grains/peas, fertilizer) variability functions based on 5-year historical data, economic returns analysis for each treatment that accounts for variability in yields, grain/pea prices, fertilizer prices. Impacts What was accomplished under these goals? Crop producers need robust agronomic tools to achieve high productivityunder low water availabilities while sustaining limited soil resources in organic farming. This project adds to this toolset byfocusing on producer-relevant response variables such as crop yield andquality, water use, soil fertility and health, andfarming profitability for organic production systems of cereal-pulse intercropping. This project also intensifies anddiversifies cropping systems for crops critical to Idaho\'s and the region\'s economy. Results from this project will highlight thebenefits of an organic production system that increases overall crop productivity, enhances soil fertility and health, andimproves crop resilience to drought stress, by adding structuraland functional diversitiestoagroecosystems. Objective 1: Understand the effects of cereal-pea intercropping systems on crop productivity, soil health and fertility, and enhanced diversity of crops and soil microbes under well-watered and drought-stressed conditions during the organic transition. The second-year field experiment was successfully established as we proposed. Plant and soil samples have been collected for cropgrowth and productivity as well as soil health and fertility for 2023 and are being processed. Soil greenhouse gas emissions were measured intensively during the 2023 growing season. We are finalizing sample and data analyses for 2022. The grain yield of monocropping wheat in 2022 wasgreater than intercropping treatments of 50%Wheat+50%Pea and 75%Wheat+50%Pea under drought stress. Under well-watered conditions, monocropping wheat producedthe highest grain yield followed by 75%Wheat+25%Pea and 75%Wheat+50%Pea. Barley grain yield under well-watered conditions was greater than drought-stressed conditions in 2022. Among the intercropping treatments,monocroppingbarley produced a greater yield than 50%Barley+50%Pea, 75%barley+75%pea, and 75%barley+50%pea, while no significant difference was found between these three intercropping treatments.Wheat end-use quality (e.g., flour protein, flour yield, and cookie diameter) was not significantly affected by the water regime or cropping system.According to the first-year results, higher intercropping seeding rates of small grains(i.e., 75%cereal+50%pea, and 75%cereal+75%pea) would not return higher cereal yields or quality. Itcould be due to high soil residual nutrients from oat green manures in 2020 and 2021. We are looking forward toresults from years 2 and 3 with more soil nutrient depletion in monocropping treatments, and intercropping treatments of high pea seeding rates may exhibit superiority to monocropping cereals. We also noticed that pea plants grew better than small grains in 2023, probably due to the cool spring that favored pulse crop growth. We expect to see high pea yields this year and large yearly variability. Objective 2: Involve undergraduate and graduate students in working on the project and include the project in course materials. We have involved 1 undergraduate and 3 Ph.D. students working on this project. This project has been incorporated into the chapter on organic farming in PLSC407 Field Crop Production in spring 2023. Objective 3: Determine the overall economic return of intercropping production under irrigated and dryland conditions during organic transition and on organic farms and transfer findings from the project to stakeholders and the public via a robustextension and outreach plan. We demonstrated our project to stakeholders and the public at 11events. The proposed webpage is under development (https://www.croppingsystems.org/). Participants of our extension events have become more aware of the option of cereal-pea intercropping systems, especiallyin organic transition and organic farming. Our project was highlighted in a newspaper article: UI researcher seeks to help farmers overcome a barrier in transitioning to organic. John O\'Connell. Intermountain Farm & Ranch, December 1, 2022. https://www.postregister.com/farmandranch/crops/ui-researcher-seeks-to-help-farmers-overcome-a-barrier-in-transitioning-to-organic/article_9084b772-718d-11ed-9265-af93b85772a5.html For economic analyses, we have gathered data on barley, pea, and wheat seed prices as well as fertilizer prices. We have also developed aninitial spreadsheet-based framework for calculating revenues (yield x price) for each treatment based on 2022 field data of average yields.Our team has discussed with growers the potential marketability of barley/pea and wheat/pea harvested simultaneously and sold for use in organic animal feed or soups. Publications Type: Other Status: Published Year Published: 2022 Citation: Lee, H., X. Liang, Z. Kayler. Crop growth of cereal-pea intercropping systems under drought stress. ASA-CSSA-SSSA Annual Meetings. Baltimore, MD, November 6-9, 2022. Progress 09/01/21 to 08/31/22 Outputs Target Audience: We demonstrated our project at multiple events, and target audiences include growers, crop consultants, industry agronomists, representatives of commodity groups (i.e., Idaho Barley Commission and Idaho Wheat Commission), graduate students, researchers, and the general public. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? A Ph.D. student has been recruited to work on the agronomy and crop ecophysiology section of the project as her dissertation project. She has been working intensively with PIs. An undergraduate worked closely with the Ph.D. student and PIs to assist with plant and soil sample collection and processing. How have the results been disseminated to communities of interest? We demonstrated our project at the events below: Cereal-based intercropping systems under full and deficit irrigation. Aberdeen Field Day, Aberdeen, ID, July 19, 2022; Tetonia field day, Tetonia, ID, July 27, 2022. (2 presentations) Cropping system diversity. Aberdeen Twilight Tour, Aberdeen, ID. July 13, 2022 Barley-pulse intercropping systems. Scoular Field Day, Jerome, ID, June 28, 2022 Field project updates on cereal intercropping systems. UI Pest Management Research Tours, Aberdeen, ID, June 28, 2022 Cereal-pea intercropping systems in organic transition. UI Pest Management Research Tours, Kimberly, ID, June 22, 2022 Cereal-pulse cropping systems. USDA NRCS 5 for 5 Soil Health (webinar). March 10, 2022 What do you plan to do during the next reporting period to accomplish the goals? With more complete results by the end of 2022, we can incorporate this project into course materials in spring 2023. We can also share the more solid results (e.g., crop yield and quality) with growers at meetings or workshops in fall 2022 and spring 2023. Impacts What was accomplished under these

goals? Producers in Idaho, other western states, and across the nation need robust agronomic tools to achieve high productivity under different water availabilities while sustaining limited soil resources in organic farming. This project adds to this toolset by focusing on producer-relevant response variables such as crop yield, crop quality, water use, soil fertility and health, and farming profitability for the proposed organic production system of cereal-pulse intercropping. This project also intensifies and diversifies cropping systems for crops critical to Idaho's and the region's economy. Results from this project will highlight the benefits of an organic production system that increases overall crop productivity, enhances soil fertility and health, and improves crop resilience to drought stress, by adding horizontal, vertical, structural, and functional diversity to agroecosystems. Objective 1:Understand the effects of cereal-pea intercropping systems on crop productivity, soil health and fertility, and enhanced diversity of crops and soil microbes under well-watered and drought-stressed conditions during the organic transition. We established the field experiment for the first year as we proposed. Plant and soil samples have been collected for crop growth and productivity as well as soil health and fertility. Soil greenhouse gas emissions were measured at the end of the growing season. We focused our efforts on CO_2 since the soils were dry at this time and we did not detect noticeable increases in concentrations of CH_4 or N_2O. Soil gas flux in full irrigation plots was greater than the deficit, except for monocropping barley where sampling resolution was too small to distinguish the water treatment. The intercropping of cereals at 75% with peas at 50% produced the largest soil CO_2 flux, suggesting a higher metabolic activity for these plots. The majority of weeds were common lambsquarters, and weed biomass from plots of wheat-pea intercropping and monocropping wheat was greater than treatments of 75%barley+25%pea and 75%balrey+75%pea. Weeds were sampled early in the growing season shortly after irrigation treatments were initiated, so weed biomass was not strongly affected by irrigation treatment. Significant differences in normalized difference vegetation index (NDVI) were found at stages of stem elongation and heading, and monocropping barley and intercropping barley treatments with high proportions of barley (e.g., 75%barley+75%pea) usually showed greater NDVI than other treatments. Plant biomass at the heading stage was significantly affected by cereal-pea intercropping treatment, and biomass from treatments of 75%barley+25%pea, 75%barley+75%pea, monocropping barley, and 50%barley+50%pea was greater than monocropping wheat and pea. At this stage, biomass under full irrigation was slightly greater than deficit irrigation. So far, monocropping barley and barley-pea intercropping treatments have shown superiority to monocropping and/or intercropping wheat treatments in terms of weed suppression, canopy development, and biomass production. Objective 2:Involve undergraduate and graduate students in working on the project and include the project in course materials. We have involved 1 undergraduate and 1 Ph.D. student working on this project. Objective 3:Determine the overall economic return of intercropping production under irrigated and dryland conditions during organic transition and on organic farms and transfer findings from the project to stakeholders and the public via a robust extension and outreach plan. We demonstrated our project to stakeholders and the public at 7 extension events. The proposed webpage is under development. Participants of our extension events have becomeaware of the option of cereal-pea intercropping systems in organic transition and organic farming.
Publications

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Cover Cropping and Crop Rotation Strategies in Organic Vegetable Production Systems to Build Soil Health and Improve Yield and Profitability

Accession No.	1027357
Project No.	MOLULU2021Hurisso
Agency	NIFA MO.X\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2021-51106-35674
Proposal No.	2021-04808
Start Date	01 SEP 2021
Term Date	31 AUG 2024
Grant Amount	$500,000
Grant Year	2021
Investigator(s)	Hurisso, T.; Reinbott, TI, MA.; Eaton, TO, .; Su, YE, .; Patel, JA, .; Akotsen-Mensah, CL, .

NON-TECHNICAL SUMMARY

Vegetable growers in Missouri and other nearby states face unique challenges during transition from conventional to organic systems including soil erosion, poor soil quality/fertility, and weed pressure, all of which likely contributes to reduced yield and profitability. According to recent surveys of organic and non-organic vegetable growers in Missouri and the North Central Region, there is a great deal of interest in the use of cover crops to increase the soil\'s organic matter content and suppress weeds in vegetable production systems. However, the concern is that farmers will often have to take land out of cash crop production every other year or more to grow cover crops as they build up soil health, a practice that will inevitably reduce economic returns, limiting organic adoption in the region. An alternative method of integrating living perennial cover crops between rows of vegetable crops is proposed to enable farmers to simultaneously build soil health while keeping land in cash crop production. The multi-year nature and extensive root systems of perennial cover crops is expected to not only reduce soil erosion, nutrient runoff, and build soil health, but also simultaneously improve farmer income due to decreased annual inputs and associated costs. Specifically, this research project will evaluate the potential of using perennial grass/legume cover crop mixes in the travel paths between production rows of vegetables to build soil health and suppress weeds during the three-year organic transition period within a vegetable family crop rotation. Outcome of this research will include (1) an improved knowledge of the extent to which ecosystem services including soil health improvement, weed suppression, and cash crop yield generated from the use of perennial grass/legume cover crop mixes in the travel paths between vegetable production rows, and (2) increased use of perennial cover crop-based alternative weed management practices in vegetable production systems in the North Central Region.

OBJECTIVES

The overall goal of this project is to improve the competitiveness of organic vegetable producers in Missouri and surrounding states by evaluating the effectiveness of various combinations of perennial grass/legume cover crops and crop rotation strategies (that fit well into the high-management requirement typical of organic vegetable production) in increasing yield and profitability, suppressing weeds, and providing adequate soil fertility while improving cover crop ecosystem services of soil health and resilience to insect pests and diseases. Our central hypothesis is that current method of weed control used by organic vegetable producers is detrimental to soil health, and that a new strategy is required in which stakeholders (both growers and scientists) co-produce the knowledge and strategies required to improve agronomic, economic, and environmental performance of organic vegetable production systems in Missouri and the Midwest region. We will work toward our goal through the following specific objectives. Objective 1: Quantify soil health changes under perennial grass/legume cover crop mixes grown in travel paths between vegetable production beds - including soil physical, chemical and biological characteristics - relative to annual cover crops and no cover crop controls. Objective 2: Quantify the potential of perennial grass/legume cover crop mixes grown in travel paths between vegetable production beds to reduce insect pests, weeds, and diseases relative to annual cover crops and no cover crop controls. Objective 3: Quantify yield of succeeding vegetable crops and nutrient uptake following 3-years of continuous perennial grass/legume cover crop mixes grown in travel paths between vegetable production beds relative to annual cover crops and no cover crop controls. Objective 4: Conduct participatory on-farm research to leverage grower experience and knowledge to inform research strategies and assess the potential benefits and challenges of integrating perennial and/or annual grass/legume cover crop mixes into diversified vegetable production systems in Missour and nearby states. Objective 5: Conduct an economic analysis using prices of vegetable crops and other agronomic inputs (e.g., seeds, fertilizers, etc.) to help producers make profitable decision on whether to grow perennial grass/legume cover crop mixes in travel paths between vegetable production beds or take land out of production to grow annual cover crops. Objective 6: Share project results with diverse stakeholders within and beyond Missouri through field days, conference presentations, extension bulletins, and peer-reviewed publications.

APPROACH

Objective 1: A replicated field experiment manipulating a full suite of perennial and annual grass/legume cover crop combination scenarios will be established at one of Lincoln University\'s research farms near Jefferson City, MO. The factorial experiment will consist of a randomized complete block design with 4 blocks, where cover crops are treated as the main plot factor, with identity of the vegetable family (Cucurbitaceae, Brassicaceae, Solanaceae) initiating the rotation sequence as the split-plot factor. Multiple soil health indicators recognized by the USDA-NRCS as well as standard nutrient parameters (pH, CEC, extractable nutrients) will be measured from each treatment combination. Objective 2: We will determine which cover crop combination scenarios, represented by different perennial grass/legume treatments and rotation strategies provide the best resilience against weeds, insect pests, and diseases pressures when compared to annual cover crops or business as usual vegetable production systems without cover crops. We will monitor presence of key insect pests (e.g., cucumber beetles, squash bugs, aphids, native and invasive stink bugs and natural enemies) through a combination of visual observations of random samples of 8-10 vegetable plants and baited and unbaited traps in treatment and control plots. Insect data will be collected biweekly during the growing season. We will assess arthropod total abundance and also calculate Shannon-Weiner diversity index. Similarly, important foliar and root diseases will be assessed in treatment and control plots. The diseases will be rated by visually assessing the percentage of symptomatic tissues on 5-10 randomly selected plants per plot. Objective 3: We will measure cash crop yield and nutrient uptake from each treatment combination. At each harvest session, the number and weight of mature marketable vegetable leafs and/or fruits harvested per replicate plot will be recorded. Quality of all tomato and cucumber fruits as well as kale leaves will be graded at harvest as marketable #1 (best), #2 (commercial), and cull (unmarketable). To determine treatment effects on plant nutrient concentrations, leaf samples from tomatoes, cucumbers and kale plants will be collected during peak harvest. Plant nutrient uptake will be calculated from plant nutrient concentrations and dry matter yield of vegetable crops. Objective 4: We will conduct on-farm trials to integrate grower experience and knowledge into research strategies and address local factors (soil types, crop mixes, and growing styles) causing variability in on-farm performance of cover crops. The on-farm trials will be conducted at two locations in Missouri and one location in Kansas and will vary farm-to-farm. Farmers will evaluate different cover crop-cash crop companion production systems visually with photographs of production fields and through qualitative ratings of system attributes (soil quality, cash crop yield, labor requirement, pest and disease pressure, and overall economic performance). Additionally, data obtained from the on-farm trials (cash crop yields) will be used along with prices of cash crops and other production inputs to perform economic analysis described in Objective 5. The on-farm trials will also be host to outreach activities described in Objective 6 and provide case-study examples for classroom instruction. Objective 5: To help vegetable producers understand the costs and benefits of growing perennial cover crops versus annual cover crops or business as usual vegetable production practice using tillage to control weeds, we will collect economic data related to treatments throughout the study. The economic analysis will be conducted in three steps: an annual growing season direct cost of production (step 1), a 3-year total system benefit analysis (step 2), and converting the cumulative costs and benefits back to a season-long enterprise budget (step 3). Objective 6: We will implement a multi-dimensional outreach and engagement plan consisting of several relevant methods to disseminate project results among stakeholders within and beyond Missouri. To reach large and diverse audiences, we will also partner with MU Extension and e-Organic. Study results will be disseminated to our target audiences through the following mechanisms:Traditional field days.Virtual field days where field-walkover video featuring both on-station research plots and in-field discussion with grower-collaborators will be hosted on Lincoln University website and MU Extension YouTube channel to be viewed by Missouri vegetable growers, while also providing regional and national impact.Presentations at regional and national grower and professional conferences such as Great Plains Growers Conference (GPGC), Mid-American Organic Association (MOA), Midwest Organic and Sustainable Education Services (MOSES) conferences, and American Society of Agronomy-Crop Science Society of America-Soil Science Society of America (ASA-CSSA-SSSA) meetingsWorkshops targeted at underserved minority farmers.Newsletter articlesCase study publications.A Master\'s thesis. Progress 09/01/23 to 08/31/24 Outputs Target Audience:Organic and non-organic vegetable producers from Missouri and neighboring states, scientists, students, and Extension specialists. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?1 MSc level graduate student trained. 1 Postdoctoral associated trained. How have the results been disseminated to communities of interest? A video story of the replicated experimental plots at LU\'s Alan T. Busby Research Farm was produced (https://youtu.be/tOMBoRVL29o), generating163 views at the time when this reported was written. The video story is also published by the popular Cover Crop Strategies webcast (https://www.youtube.com/watch?v=HkUiyRgtgiM), generating 289 views at the time of writing this report. Lincoln University Cooperative Extension is currently partnering with the Columbia Center for Urban Agriculture (CCUA) to train a new generation of farmers in central Missouri. On July 29, 2024, a group of 17 apprenticeships visited the Organic Transitions project plots at LU\'s Alan T. Busby Research Farm and learned about vegetable-cover crop companion production strategies. On January 12-13, 2024, Project Director Tunsisa Hurisso presented poster at the 2024 Great Plains Growers Conference in St. Joseph, Missouri. The title of the poster presentation was: \"Soil Health and Vegetable Yield Responses to Perennial versus Annual Cover Crops in Traffic Pathways.\" On 24 June 2024, graduate student Poonam Karki successfully defended her master\'s thesis titled \"Integrating Living Perennial Cover Crops into Organic Vegetable Systems: Impacts on Soil Health and Cover Crop Biomass Production.\" Graduate student poster presentation: Poonam Karki presented a poster tilted \"Integrating Living Perennial Cover Crops into Organic Vegetable Systems: Impacts on Soil Health and Cover Crop Biomass Production\" at the 21st Symposium of the Association of 1890 Research Directors Inc. (ARD) held in Nashville, Tennessee, from April 6-9, 2024. She once again won a 3rd place award for her poster presentation. Graduate student poster presentation: Poonam Karki gave poster presentation at the Agronomy, Crop, and Soil Science Societies of America international conference held in St. Louis, Missouri, from October 29-November 1, 2023. Poonam Karki won a 1st place graduate student poster competition. The title of her poster was: \"Evaluation of Labile C and N Indicators of Soil Health After 2-years of Living Perennial and Annual Cover Crops During Organic Vegetable Transition.\" What do you plan to do during the next reporting period to accomplish the goals?This is the third year of the field season which will end in late September 2024, and we will need to collect final yield and soil data.We are planning on having three years of data to present at three major meetings: American Society of Agronomy in November 2024. Great Plains Growers Conf. in January 2025. Midwest Organic and Sustainable and Extension Conf. in February 2025. These meetings are critical for sharing scientific results with both the scientific community as well as the producers. Producing a podcast and video stories on the three-year results of our study is a large part of this grant and we plan on doing that in fall 2024 and winter 2025 after we have all of the yield and soil health results. Impacts What was accomplished under these goals? Below are Year 3 accomplishments broken down by the project objectives. Accomplishments by Objective Objective 1: Evaluate the impact of integrating perennial vs. annual grass/legume cover crop mixes into travel paths between vegetable production rows on soil health, weeds, and insect pests and diseases. Task 1: To achieve Objective 1, the following activities were performed: At the LU\'s Alan T. Busby Research Farm, a certified organic research farm, replicated plots that consisted of 4-feet wide vegetable production beds separated by 6-feet wide walkways have been established in Year 1 of the study. The pathways between vegetable production beds were either seeded with cover crops or tilled for weed management (i.e., no cover crop control). Perennial ryegrass/white clover mix (Treatment 1) and orchard-grass/red clover mix (Treatment 2) were drill seeded in mid-October 2021 and mowed periodically since then. A mixture of sorghum-sudangrass and annual sweet clover (Treatment 3) was seeded each year: May 2022, May 2023, and May 2024. Each year, vegetable production beds were planted in an off-season cover crop mixture of winter wheat and Austrian winter peas (except for the no cover crop control): October 2021, October 2022, and October 2023. Between March and mid-May 2024, cucumber, kale and tomato transplants were propagated in the greenhouse located at Alan T. Busby Research Farm and the seedlings were transplanted in the vegetable production beds in late-May 2024 following termination of the winter wheat and Austrian winter pea cover crop mix. Soil samples collected after the final round of vegetable harvest in Year 1 and 2 have been analyzed for a multitude of soil health indicators. Using the soil data from Years 1 and 2, graduate student Poonam Karki gave poster presentation at the Agronomy, Crop, and Soil Science Societies of America international conference held in St. Louis, Missouri, from October 29-November 1, 2023. Poonam Karki won a 1st place graduate student poster competition. The title of her poster was: \"Evaluation of Labile C and N Indicators of Soil Health After 2-years of Living Perennial and Annual Cover Crops During Organic Vegetable Transition.\" Poonam Karki presented another poster tilted \"Integrating Living Perennial Cover Crops into Organic Vegetable Systems: Impacts on Soil Health and Cover Crop Biomass Production\" at the 21st Symposium of the Association of 1890 Research Directors Inc. (ARD) held in Nashville, Tennessee, from April 6-9, 2024. She once again won a 3rd place award for her poster presentation. On 24 June 2024, Poonam Karki successfully defended her master\'s thesis titled \"Integrating Living Perennial Cover Crops into Organic Vegetable Systems: Impacts on Soil Health and Cover Crop Biomass Production\" and officially completed her MSc degree program. She is currently hired as a research associate (0.5 FTE) to continue working on the same project. On January 12-13, 2024, Project Director (Tunsisa Hurisso) presented poster at the 2024 Great Plains Growers Conference in St. Joseph, Missouri. The title of the poster presentation was: \"Soil Health and Vegetable Yield Responses to Perennial versus Annual Cover Crops in Traffic Pathways.\" Objective 2: Determine the impact of integrating perennial vs. annual grass/legume cover crop mixes into travel paths between vegetable production beds on vegetable crop yields and nutrient uptake. Task 2: To achieve Objective 2, the following activities were performed: Kale (variety Darkibor F1), cucumber (variety Paraiso), and tomato (variety Galahad) were planted in late-May 2024, and currently all of them are being harvested until first week of September 2024. From the start of 1st harvest in late June 2024 up until now, 1352 pounds of cucumber, 217 pounds of kale, and 140 pounds of tomato have been donated to two food pantries (Catholic Charities of Northern and Central Missouri and the Samaritan Center in Jefferson City, Missouri) after completion of produce yield data collection. Cover crop aboveground biomass data is being collected until the end of September 2024. Biomass samples from Year 1 and 2 of the study were ground and analyzed for carbon and nitrogen content at University of Missouri Soil and Plant Testing Laboratory. Objective 3: Conduct collaborative on-farm research to assess the potential benefits and drawbacks of integrating perennial and/or annual grass/legume cover crop mixes into diversified vegetable systems in Missouri and Kansas. Task 3: To achieve Objective 3, the following activities were performed: Three collaborator producers are involved in this study. The type of vegetable crop produced at each collaborator\'s site varied based on collaborator\'s choice, but all three of them established perennial ryegrass in the pathways between vegetable production beds. For the control, the pathway had no-cover crop and involved tillage for weed control. Soil samples collected from collaborator farmer fields were analyzed for a suite of soil health indicators, including active carbon (a.k.a. permanganate oxidizable carbon, soil respiration, potentially mineralizable nitrogen, and phospholipid fatty acids). Soil test reports have been shared with the producers. Objective 4: Perform economic analyses assessing the cost of inputs, labor, and the value of marketable vegetable produce associated with each set of cover crop-cash crop companion production system relative to the corresponding control(s) considered in the study. Task 4: To achieve Objective 4, the following activities were performed: Collected data on current market price for each vegetable crop produced, along with cost of inputs (seeds of vegetables and annual cover crops). This will be used in the economic analysis at the end of the study period. Objective 5: Effectively educate diverse vegetable producers within and beyond Missouri about the implications of cover crop management strategies investigated in this study through university field days, workshops, video/virtual field days, along with farmer cooperator field days. Task 5: Activities performed in the second year of the project to achieve Obj. 5 include: A video story of the replicated experimental plots at LU\'s Alan T. Busby Research Farm was produced (https://youtu.be/tOMBoRVL29o), generating163 views at the time when this reported was written. The video story is also published by the popular Cover Crop Strategies webcast (https://www.youtube.com/watch?v=HkUiyRgtgiM), generating 289 views at the time of writing this report. Lincoln University Cooperative Extension is currently partnering with the Columbia Center for Urban Agriculture (CCUA) to train a new generation of farmers in central Missouri. On July 29, 2024, a group of 17 apprenticeships visited the Organic Transitions project plots at LU\'s Alan T. Busby Research Farm and learned about vegetable-cover crop companion production strategies. Publications Progress 09/01/22 to 08/31/23 Outputs Target Audience:Organic and non-organic vegetable producers from Missouri and Kansas states, students, and research and Extension faculty and staff from both Lincoln University of Missouri and University of Missouri-Columbia. Changes/Problems:Organic seed availability is one major problem that the project team faced during this reporting period. For example, of the organic vegetable varieties we used in year 1 of the study - i.e., \"Darkibor F1\" kale, \"Corinto F1\" cucumber, and \"Wisconsin 55\" tomato - seeds of the latter two were unavailable in the market for year 2 of the study. Thus, \"Paraiso\" cucumber and \"Galahad\" tomato varieties were used in place of Corinto F1 and Wisconsin 55, respectively. What opportunities for training and professional development has the project provided? A graduate student, Poonam Karki, who was recruited as part of this project has successfully completed first year of coursework and involved in the ongoing research including field data collection, laboratory analyses of samples, and will present first and second year project results in the the 2023 Agronomy Society of America, Crop Science Society of America, and Soil Science Society of America meeting, which will be held from October 29-November 1 in St. louis, Missouri. One postdoctoral research associate who is partially supported by the project has been trained in the laboratory procedures to conduct a multitude of soil health tests including soil respiration via 24-hour CO2 evolution, permanganate oxidizable carbon, several enzyme activities, and ACE soil protein at the PD\'s lab. How have the results been disseminated to communities of interest? Lincoln University Cooperative Extension is currently partnering with the Columbia Center for Urban Agriculture to train the new generation of farmers in central Missouri. On July 24, 2023, a farm tour was held to showcase the Organic Transitions project plots at LU Alan T. Busby Research Farm. There were 15 participants. As described above, an abstract has been submitted and accepted by the Agronomy Society of America, Crop Science Society of America, and Soil Science Society of America and a graduate student will present project results from first two years of study at the meeting. What do you plan to do during the next reporting period to accomplish the goals?The project team will continue the tasks/activities described under each of the five project objectives just as it has been done in the first two years of the study.While the ORG granting period runs only for 3-years (fall 2021-summer 2024), this project was designed in a such way that in year 4 of the study (i.e., fall 2024 - summer 2025), the vegetable beds will be moved over to the pathways where cover crops had been growing for three consecutive years, allowing the research team to evaluate the cumulative impacts of three-years of annual vs. perennial cover crops on soil health, yields of vegetables, and other effects including weed density and diversity as well as insect pests and diseases. Thus, we will likely request a no-cost extension after next reporting period. Impacts What was accomplished under these goals? Below are year 2 accomplishments broken down by the project objectives. Project Progress by Objective Objective 1: Evaluate the impact of integrating perennial vs. annual grass/legume cover crop mixes into travel paths between vegetable production rows on soil health, weeds, and insect pests and diseases. Task 1: Activities performed in the second year of the project to achieve Obj. 1 include: At the LU\'s Alan T. Busby Research Farm, a certified organic research farm, replicated plots that consisted of 4-feet wide vegetable production beds separated by 6-feet wide walkways have been established in year 1 of the study. The pathways between vegetable production beds were either seeded with cover crops or tilled for weed management (i.e., no cover crop control). Perennial ryegrass/white clover mix (Treatment 1) and orchard-grass/red clover mix (Treatment 2) were drill seeded in mid-October 2021 and mowed periodically since then. A mixture of sorghum-sudangrass and annual sweet clover (Treatment 3) was first seeded in May 2022 and again in May 2023; The vegetable beds were planted in an off-season cover crop mixture of winter wheat and Austrian winter peas (except for the no cover crop control) in October 2021 and again in October 2022. The latter was tilled into the soil in mid-May 2023 prior to planting vegetable crops; Between March and mid-May 2023, cucumber, kale and tomato transplants were propagated in the greenhouse and the seedlings were transplanted in the vegetable production beds in late-May 2023 following termination of winter wheat and Austrian winter peas; Soil samples collected after the final round of vegetable harvest in year 1 have been analyzed for a multitude of soil health indicators; Using the soil data from year 1 & 2, an abstract has been submitted to the 2023 Agronomy Society of America, Crop Science Society of America, and Soil Science Society of America meeting, which will be held from October 29-November 1 in St. louis, Missouri. A graduate student, Poonam Karki, who was recruited as part of this project will present first year project results in the meeting. Objective 2: Determine the impact of integrating perennial vs. annual grass/legume cover crop mixes into travel paths between vegetable production beds on vegetable crop yields and nutrient uptake. Task 2: Activities performed in the second year of the project to achieve Obj. 2 include: Collected 2nd year vegetable harvest data. (Note: Of the organic varieties we used in year 1 of the study - i.e., \"Darkibor F1\" kale, \"Corinto F1\" cucumber, and \"Wisconsin 55\" tomato - seeds of the latter two were unavailable in the market for year 2 of the study. Thus, \"Paraiso\" cucumber and \"Galahad\" tomato varieties were used in place of Corinto F1 and Wisconsin 55, respectively.) All three vegetables (Darkibor F1, Paraiso, Galahad) were planted in late-May 2023, harvested during the summer, and will continue to do so until end of September. Thus far, more than 1000 pounds of produce have been donated to Catholic Charities of Northern and Central Missouri and to the Samaritan Center in Jefferson City, MO, after completion of produce yield data collection; Collected 2nd year cover crop aboveground biomass data and will continue to do so until end of September; Cover crops biomass samples from both 1st and 2nd year of the study have been ground and will soon be analyzed for carbon and nitrogen content at University of Missouri Soil and Plant Testing Laboratory. Objective 3: Conduct collaborative on-farm research to assess the potential benefits and drawbacks of integrating perennial and/or annual grass/legume cover crop mixes into diversified vegetable systems in Missouri and Kansas. Task 3: Activities performed in the second year of the project to achieve Obj. 3 include: All three of our collaborating producers visited the replicated experimental plots at LU Alan T. Busby Research Farm in August 2022. Then, all three of them established their own on-farm trials in October 2022. They spaded the vegetable production beds, then spadedthe test plot pathways and left the control as is. They hand broadcast all cover cropseeds. The perennial ryegrass in the pathways established well. Clover not as much, but there is some. They only needed to mow the pathways once since establishment. One of the producers commented: \"I like the rye in the pathways. It\'s very pleasant to work in. The control pathways had a lot of spiky weeds (like thistle and horse nettle) and morning glory.\" The winter wheat all came up in the production areas and was decent cover. Producers flail mowedthe wheat and spaded in the residue in May 2023. Vegetable crops were planted into white on black plastic in late May 2023. At one location, all vegetable crops struggled and were destroyed in July by a swarm of blister beetles. They did not recover. According to the producer, June\'s dry hot weather was too much for all the plants.

The plants were irrigated, but it only helped so much. Objective 4: Perform economic analyses assessing the cost of inputs, labor, and the value of marketable vegetable produce associated with each set of cover crop-cash crop companion production system relative to the corresponding control(s) considered in the study. Task 4: Activities performed in the second year of the project to achieve Obj. 4 include: Collected data on current market price for each vegetable crop produced, along with cost of inputs (seeds of vegetables and cover crops). This will be used in the economic analysis at the end of the study period. Objective 5: Effectively educate diverse vegetable producers within and beyond Missouri about the implications of cover crop management strategies investigated in this study through university field days, workshops, video/virtual field days, along with farmer cooperator field days. Task 5: Activities performed in the second year of the project to achieve Obj. 5 include: In October 2021 (1st year of the study), demonstration plots were established at the University of Missouri (MU) Jefferson Farm and Garden where a 90-feet by 84-feet area was split into nine 4-feet wide vegetable productions rows, alternating with 6-feet wide travel pathways. (Note: The demonstration plots at MU\'s Jefferson Farm and Garden are replicated only two times); Travel pathways between vegetable production beds were either seeded with cover crop mixtures of ryegrass/white clover, orchard-grass/red clover, sorghum-Sudangrass and annual sweet clover, or tilled to simulate the favored method used by vegetable growers to control weeds between vegetable productions beds; In year 2, vegetable production beds were planted in an off-season cover crop mixture of winter wheat and Austrian winter peas in fall 2022, terminated in May 2023, and vegetables were transplanted in early-June 2023; In summer 2023, the project team will be showcasing the demonstration plots at Jefferson Farm and Garden at the popular Tomato Festival on September 7th (annual attendance 1000+). Additionally, video stories of the demonstration plots at Jefferson Farm and Garden and the replicated experimental plots at LU Alan T. Busby Research Farm will be done in September 2023. Lincoln University Cooperative Extension is currently partnering with the Columbia Center for Urban Agriculture to train the new generation of farmers in central Missouri. On July 24, 2023, a farm tour was held to showcase the Organic Transitions project plots at LU Alan T. Busby Research Farm. There were 15 participants. Publications **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience: Organic and non-organic vegetable growers from Missouri and Kansas, students, and research and Extension faculty and staff from both Lincoln University of Missouri and University of Missouri-Columbia. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? One MS-level graduate student (Poonam Karki) has been recruited and started her coursework in fall 2022-semester. How have the results been disseminated to communities of interest? A news article has been distributed to local and regional media outlets highlighting first year project progress (see <https://www.lincolnu.edu/news/2022/10/usda-organic-transitions-farming-grant.html>). What do you plan to do during the next reporting period to accomplish the goals? This is a 3-year project involving research at Lincoln University of Missouri Alan T. Busby Organic research Farm, demonstration at University of Missouri's Jefferson Farm and Garden, and on-farm research/innovation trials at cooperator producer sites. For the next reporting period, we plan to continue collecting research data from LU's Alan T. Busby Organic Research Farm, hosting field days at both MU's Jefferson Farm and Garden as well as at producers' sites, including presentation of results at regional/national conferences by the graduate student and the PD. **Impacts** What was accomplished under these goals? Summary Year 1 was a big success. Following NIFA's official award notification, Lincoln University (LU) Marketing and University Relations issued press release in September 2021 to make official announcement on the project; we held project initiation and planning meeting (via Zoom) with our project advisory board on October 4th, 2021; conducted a baseline soil sampling and established fully replicated experimental plots at Lincoln University (LU) Alan T. Busby Organic Research Farm, seeded our perennial cover crop treatments in late-September / early October of 2021, planted the annual cover crop treatment and vegetable crops in May 2022, collected first year cover crop aboveground biomass and vegetable harvest data, collected soil samples after first year vegetable harvest; established demonstration plots at University of Missouri Jefferson Farm and Garden; recruited MS-level graduate student (Poonam Karki) who started her coursework in fall 2022-semester; distributed a News article in September 2022 to publicize the first year project progress (<https://www.lincolnu.edu/news/2022/10/usda-organic-transitions-farming-grant.html>), and have established three on-farm trials at our cooperator-producers sites where cover crops of producers' choice were seeded in October 2022. Below are our year 1 accomplishments, in brief. Project Progress by Objective Objective 1: Evaluate the impact of integrating perennial and annual grass/legume cover crop mixes into travel paths between vegetable production rows on soil health, weeds, and pests (insects and diseases). Critical Accomplishments Task 1: During the first year of the project performance period, multiple activities were performed including the following: -Following NIFA's official award notification on 15 September 2021, Lincoln University (LU) Marketing and University Relations Office made an official announcement on the project; -On 4 October 2021, a project advisory board meeting was held via Zoom for planning and project initiation including discussion centered around selection of cover crop treatments for the on-farm trials; -At the LU's Alan T. Busby Research Farm, a certified organic research farm, we established replicated plots that consist of 4-ft. wide vegetable production beds separated by 6-ft. wide traffic paths, or walkways. The traffic paths between vegetable production beds were either seeded with cover crops or tilled for weed management (i.e., no-cover tilled control). Ryegrass/white clover mix (Treatment 1) and orchard-grass/red clover mix (Treatment 2) were drill seeded in mid-October 2021. A mixture of sorghum-sudangrass and annual sweet clover (Treatment 3) was seeded in May 2022; -The vegetable beds were planted in an off-season cover crop mixture of winter wheat and Austrian winter peas (except for the no-cover tilled control) in October 2021. The winter wheat and peas were tilled into the soil in May 2022 to help provide nitrogen for vegetable crops; Cucumber, kale and tomato transplants were produced in the greenhouse and transplanted in the vegetable production beds in May 2022 following termination of winter wheat and Austrian winter peas; -Following the final vegetable harvest, we collected soil samples in late-September 2022. The soil samples are being analyzed for multiple soil health indicators. Objective 2: Determine the impact of integrating perennial and annual grass/legume cover crop mixes into travel paths between vegetable production beds on vegetable crop yields and nutrient uptake. Task 2: Activities performed to achieve Objective 3 include the following: -Collected first year vegetable harvest data. Three vegetable varieties (Darkibor F1 organic kale, Corinto F1 organic cucumber, and Wisconsin 55 organic tomato) that were planted in late-May 2022 have been harvested during the summer and fall of 2022. -Donated more than 1000 pounds of produce to Catholic Charities of Northern and Central Missouri after completion of produce yield data collection; -Collected first year cover crop aboveground biomass data;Note: Nutrient uptake data will be collected in the 4th year of the project when vegetable production beds are moved over to cover cropped areas. Objective 3: Conduct collaborative on-farm research to assess the potential benefits and drawbacks of integrating perennial and/or annual grass/legume cover crop mixes into diversified vegetable systems in Missouri and Kansas. Task 3: To achieve Objective 3, activities performed include the following: -Established demonstration plots at the University of Missouri (MU) Jefferson Farm and Garden where a 90-ft. by 84-ft. area was split into nine 4-ft. wide vegetable productions rows, alternating with 6-ft. wide travel pathways. (Note: The demonstration plots at MU's Jefferson Farm and Garden are replicated only two times); -The vegetable production beds were planted in an off-season cover crop mixture of winter wheat and Austrian winter peas (except for the no-cover tilled control) in October 2021; -In spring 2022, the travel pathways between vegetable production beds were either seeded with cover crop mixtures of ryegrass/white clover (Treatment 1), orchard-grass/red clover (Treatment 2), sorghum-Sudangrass and annual sweet clover (Treatment 3), or tilled to simulate the favored method used by vegetable producers to control weeds between vegetable productions beds; -Three vegetable crop varieties (Darkibor F1 organic kale, Corinto F1 organic cucumber, and Wisconsin 55 organic tomato) were transplanted in the vegetable production beds in May 2022 following termination of winter wheat and Austrian winter peas; -Established three on-farm trials at our cooperator-producer sites where a cover crop mixture of perennial ryegrass/white clover was seeded in October 2022. Objective 4: Perform economic analyses assessing the cost of inputs, labor, and the value of marketable vegetable produce associated with each set of cover crop-cash crop companion production system relative to the corresponding control(s) considered in the study. Task 4: Activities performed under Objective 4 include the following: -Vegetable market price, along with production input (vegetable and cover crops seeds) cost, has been collected and will be used for economic analysis. Objective 5: Effectively educate diverse vegetable producers within and beyond Missouri about the implications of the advanced cover crop management practices investigated in this study through university field days, workshops, video/virtual field days, along with farmer cooperator field days. Task 5: Regarding Objective 5, activities performed include the following: -On 11 August 2022, held two field days. One at LU Alan T. Busby Research Farm (11 participants) and another at MU's Jefferson Farm and Garden (7 participants) to showcase the research and demonstration plots to the stakeholders; -On 3 November 2022, conducted a farm tour at one of the cooperator productors' site (Millsap Farm). There were eight participants at the event. -Distributed a news article titled \"Lincoln University of Missouri Researchers Tackle Weed control in Organic Crops\" to local and regional media outlets for possible coverage in spring 2023. The news article is published at LU's website (see <https://www.lincolnu.edu/news/2022/10/usda-organic-transitions-farming-grant.html>). **Publications**

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Integrated Disease Management Strategies for Key Disease(s) in Organic Tomato Production System

Accession No.	1027175
Project No.	NC09922
Agency	NIFA NC.\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2021-51106-35493
Proposal No.	2021-04809
Start Date	01 SEP 2021
Term Date	31 AUG 2025
Grant Amount	$600,000
Grant Year	2021
Investigator(s)	Panthee, D.; Louws, FR, .; Dean, RA, A..; Adhikari, TI, .; Oh, YE, YE.; Shekastband, RE, .; Zhang, JI, .

NON-TECHNICAL SUMMARY

The demand for organic tomatoes in the Southeast is high, but production is limited due to the lack of regionally adapted high-yielding varieties. Organic growers have requested research on disease management practices including improved varieties with superior fruit quality so that they can take advantage of the ever-increasing market demand. Our long-term goal is to develop sustainable approaches in disease management for organic production by integrating resistance breeding and grafting methods well-adapted to organic growing conditions in the Southeast. The proposed project will benefit farmers in the U.S. in general, and in the Southeast in particular, who need high-value crops that can be grown on small acreages. This proposal was developed through direct interaction with the organic growers. The objectives of this proposal are:(1) Determine genotypic differences for foliar and soilborne fungal disease resistance, and fruit quality in heirloom tomato varieties grown under organic conditions. (2) Identification of suitable tomato varieties and rootstocks for organic production through participatory variety selection for high yield, disease resistance, and fruit quality. (3a) Genetic analysis of host resistance to early blight (EB), Septoria leaf spot (SLS), and Southern stem blight (SSB). (3b) Assessment of resistance to pathotypes of Altenaria linariae and Septoria lycopersici using molecular markers complemented by virulence testing. (4) Disseminate knowledge gained on tomato varieties and production systems grown in organic conditions to farmers, extension agents, industry, and the general public. The proposed research is relevant to the ORG program and will facilitate the development of organic agriculture production (especially transitioning systems), biodiversity, management of priority diseases, and integrating novel technology into organic systems.

OBJECTIVES

The overarching goal of this research is to develop and recommend, through extension programming, high-yielding, disease-resistant, flavorful, nutritious tomato varieties for sustainable organic production systems. This project the following objectives: Objective 1: Determine genotypic differences for foliar and soilborne fungal disease resistance, and fruit quality in heirloom tomato varieties grown under organic conditions. Objective 2: Identification of suitable tomato varieties and rootstocks for organic production through participatory variety selection for high yield, disease resistance, and fruit quality. Objective 3a: Genetic analysis of the host resistance to early blight (EB), Septoria leaf spot (SLS), and Southern stem blight (SSB). Late blight (data sets are mature) along with these three diseases are important for organic production. Objective 3b: Assessment of resistance to pathotypes of Altenaria linariae (EB) and other pathogens including Septoria lycopersici (SLS) using molecular markers complemented by virulence testing. Objective 4: Disseminate knowledge gained on tomato varieties and production systems grown in organic conditions to farmers, extension agents, industry, and the public.

APPROACH

To achieve the first objective, in Year 1 and Year 2, we will take our most advanced lines and screen about 30 to 35 tomato genotypes including breeding lines and varieties plus resistant and susceptible controls. In years 1 and 2 each, four trials will be established to evaluate disease resistance for early blight (caused by Alternaria linariae), late blight (caused by Phytophthora infestans), and Septoria leaf spot (caused by Septoria lycopersici). Southern stem blight work will be confined to lab and greenhouse work initially since datasets are not as mature as those for the other pathosystems. Breeding lines, known susceptible controls, and known resistant controls will be established in a randomized complete block design with three replications as mentioned above. Plants will be grown under organic conditions.For fruit quality, separate from the disease evaluation, the genotypes will be evaluated and characterized at vegetative and reproductive growth stages for various plant and fruit traits. A subjective rating of each genotype for flavor will be made by untrained personnel when fruits are at the fully ripe stage, as described by (Sinesio et al., 2010). Fruits will be analyzed for lycopene, TSS, fruit color, and firmness. Total yield per plot will be recorded on physiologically mature or ripe fruits by harvesting at least three times.To achieve the second objective, we will engage with at least three cooperating certified organic farmers in NC. The growers will also be engaged in evaluations throughout the growing season. In Years 3 and 4, the 8-10 most promising varieties identified in Objective 1 will be grown on the cooperating farms. The team will work with each grower to identify the best combination of scions and rootstocks based on known disease pressure in each region of the state, the history of the farm, and grower priorities. Comparisons will be made with the results of the research station studies. On each farm, there will be at least 5 plants of each combination and two to three replications per site. Fruit yield and disease scoring data will be measured as in the first objective.To achieve the third objective, we have already developed a mapping population segregating for EB, LB, and SLS. Briefly, our experimental approach is to grow the F3 population consisting of 250 individuals and resistant and susceptible controls at Mountain Research Station, Waynesville, NC in the summer of 2022. DNA will be extracted from healthy, young seedlings and submitted to the Genome Science Lab at NC State University for GBS. Plants will be inoculated with SLS inoculum when they are six to eight weeks old. Plants will be scored for SLS two weeks after inoculation and will continue scoring every week for four to six weeks. The area under the disease progress curve (AUDPC) will be developed based on this disease score and will be used as a single phenotypic variable for QTL mapping. Single nucleotide polymorphism (SNP) molecular markers will be converted into more useful Kompetitive Allele-Specific PCR (KASP) markers. These are bi-allelic markers and easy to use like SCAR or CAPS. We will design and obtain primers from LGC Genomics (http://info.biosearchtech.com/) to convert the SNPs into KASP markers. The use of reliable molecular markers will facilitate combining the genes conferring resistance to multiple diseases including EB, LB, and SLS. Marker-assisted selection (MAS) also helps to eliminate unwanted genetic backgrounds in an early generation and identifies the most desirable gene combinations or individuals in segregating populations. We will also characterize the isolates of Alternaria linariae and Septoria lycopersicii pathogens by the whole-genome sequencing method. We are interested to identify the potential effectors that can be used to enhance the resistance. Unique \'haplotypes\' of Alternaria linariae and Septoria lycopersicii with distinct effector genes revealed in this objective will be selected and their virulence (the ability of an isolate to induce disease by overcoming resistance) will be assessed on selected tomato genotypes. Ten to 12 tomato genotypes identified from the Activity related to the first objective and (NC EBR-1 to NC EBR-8) originating from our tomato breeding programs will be selected and used in this experiment. Cultivar \'Bonny Best\' will be included as a susceptible check. Virulence assays will be conducted under controlled conditions in the greenhouse. The primary goals of the fourth objective of this project are to keep the public informed of the progress and impact of the study, keep public and private breeders informed of the relevant information and materials that arise from the project, engage farmers, and train extension agents. For that, we will have workshops and field days, development of electronic resources, giving presentations at conferences, and training undergraduate and graduate students. Progress 09/01/23 to 08/31/24 Outputs Target Audience:Our target audiences are tomato stakeholders, particularly organic tomato growers in NC, organic researchers in academic institutions, and the seed industry. We reached out to these stakeholders by making presentations at the Winter Vegetable Conference held in Asheville in February 2024 and Tomato Field Day held in August 2024. Presentations were also made at the American Phytopathological Society in July 2024, which were received very well. These presentations have helped us expand our connections with the stakeholders, which will benefit the organic industry in the US. Changes/Problems:We anticipate that the last year will remain the same. This project was implemented successfully. Next year is the last year of the project. We will focus on implementing the planned activities in the fourth year. We hope that it will go as smoothly as in other years. What opportunities for training and professional development has the project provided?Two graduate students and one post-doctoral research associate are being mentored in this project. The graduate students are graduating in the Spring or summer of 2025, whereas the post-doc is wrapping up his research by the end of this project. This will be a massive resource for the country\'s organic tomato program. We leveraged all available resources to train these people in our program. We are optimistic that they will play a pivotal role in the country\'s organic research program. How have the results been disseminated to communities of interest?We presented the results on Tomato Field Day, attended by as many as 600 stakeholders. Presentations were made on a range of diseases, including early blight, late blight, Septoria leaf spot, and southern blight. Similar presentations were made at the Winter Vegetable Conference and theAmerican Phytopathological Society. This captures the diversity of stakeholders, including tomato growers, researchers, and seed industry representatives. All of them may benefit from the information presented in these meetings. What do you plan to do during the next reporting period to accomplish the goals?Weare approaching the end of this project cycle. Next year, we will repeat the grafting experiment under on-farm conditions. We will focus on writing the final reports, including manuscripts, and working towards the second phase of this project. We will submit the second phase of the proposal and advance our research. Impacts What was accomplished under these goals? We started by screening more than 240 tomato accessions in the greenhouse for resistance to early blight and Septoria leaf spot. The experiment was replicated two timesand repeated twice. Based on this experiment, we evaluated 40 tomato lines under field conditions in theorganic unit at Mountain Research Station, Waynesville, NC. (1). In 2024, the top 14 lines were assessed in four organic production environments, including two on-farm conditions with three replications. These lines are being scored for disease resistance and yield potentials. While final data is yet to be collected, the performance of multiple lines is impressive. (2). A grafting experiment is in progress to identify a suitable rootstock to address the problem of soil-borne disease, including Sothern blight. Preliminary data indicates that NC RST-01 is more effective in managing soil-borne diseases than other rootstocks. We will present the detailed results with the complete data set by the end of this season. (3). Isolates of Alternaria, Sclerotium, and Septoria were collected from various tomato growing locations in NC. Diversity analysis and pathogenicity evaluation are underway. We are optimistic that we will get some sensible results from these experiments. (4). Various extension activitieshave been made, including presentations on Tomato Field Day, Regional and National professional meetings, and local growers\' meetings. We also tweet the important information. We will continue making such presentations in the future. Publications Type: Journal Articles Status: Published Year Published: 2024 Citation: Panthee, D.R. 2023. Improving Heat Stress Tolerance in Tomato. HortScience 58: S81-S82. Panthee, D.R., A. Pandey and R. Paudel. (2024). Multiple Foliar Fungal Disease Management in Tomatoes: A Comprehensive Approach. International Journal of Plant Biology 15: 69-93. Type: Journal Articles Status: Published Year Published: 2024 Citation: Siddique, M.I., E. Silverman, F. Louws and D.R. Panthee. (2024). Quantitative Trait Loci Mapping for Bacterial Wilt Resistance and Plant Height in Tomatoes. Plants (Basel) 13. doi:10.3390/plants13060876. Type: Journal Articles Status: Published Year Published: 2023 Citation: Adhikari, P., M.I. Siddique, F.J. Louws and D.R. Panthee. 2023. Identification of quantitative trait loci associated with bacterial spot race T4 resistance in intra-specific populations of tomato (Solanum lycopersicum L.). PLoS ONE 18: e0295551. doi:10.1371/journal.pone.0295551. Type: Conference Papers and Presentations Status: Awaiting Publication Year Published: 2024 Citation: Paudel, R., Pandey, A., Ingram, T., Panthee, D.R., Louws, F.J., and Adhikari, T.B. (2024). Exploring effector profiles of Alternaria linariae isolates in North Carolina. Phytpathology. XX; xx-xx. Type: Other Status: Published Year Published: 2024 Citation: Paudel, R., Morgan, W., Louws, F.J. and Panthee, D.R. (2024). Evaluation of different rootstocks for grafting to manage southern stem blight of tomato in NC. Department of Horticultural Science. North Carolina State University, Tomato Field Day, Aug 15, 2024, Mills River, NC. Type: Other Status: Published Year Published: 2024 Citation: Zhang, J. and Panthee, D.R. (2024). Bacterial Spot Resistance in Tomato Department of Horticultural Science. North Carolina State University, Tomato Field Day, Aug 15, 2024, Mills River, NC. Type: Other Status: Published Year Published: 2024 Citation: Siddique, M.I. and Panthee, D.R. (2024). Early Blight Resistance in Tomato. Department of Horticultural Science. North Carolina State University, Tomato Field Day, Aug 15, 2024, Mills River, NC. Type: Other Status: Published Year Published: 2024 Citation: Pandey, A., Paudel, R., and Panthee, D.R. (2024). Septoria Leaf Spot Resistance in Tomatoes. Department of Horticultural Science. North Carolina State University, Tomato Field Day, Aug 15, 2024, Mills River, NC. Type: Other Status: Published Year Published: 2024 Citation: Panthee, D.R., Morgan, W., and Cleary, S. (2024). Evaluation of Tomato Hybrids for Fruit Yield, Quality, and Disease Resistance. Department of Horticultural Science, North Carolina State University, Tomato Field Day, Aug 15, 2024, Mills River, NC. Type: Other Status: Published Year Published: 2024 Citation: Morgan, W., Cleary, S., & Panthee, D.R., (2024). Breeding for late blight resistance in tomato breeding program at NC State University. Department of Horticultural Science, North Carolina State University, Tomato Field Day, Aug 15, 2024, Mills River, NC. Type: Conference Papers and Presentations Status: Awaiting Publication Year Published: 2024 Citation: Adhikari, T.B., Olukolu, B.A., Pandey, A., Philbrick, A.N., Panthee,, D.R., Shekasteban,, R., Dean, R.A., and Louws, F.J. (2024). Genome?wide association analysis reveals novel candidate genes associated with resistance to Verticillium dahliae race 3 in tomato. Phytpathology. XX; xx-xx. Type: Conference Papers and Presentations Status: Awaiting Publication Year Published: 2024 Citation: Siddique, M.I., Blume, J., Zhang, J. and Panthee, D.R. (2024). Genetic mapping of loci conferring resistance to Septoria leaf spot in tomato. Phytpathology. XX; xx-xx. Progress 09/01/22 to 08/31/23 Outputs Target Audience:Our target audience are toamto growers in NC, tomato researchers in academia, tomato industry, and overall tomato industry people. We reached out to these stakeholdrs by making presentations on Winter Vegetable conference held at Asheville, NC, tomato field day held at Mills River, NC, professional meetings including APS and ASHS. All presentations were received by very well. Changes/Problems:We will not make any changes to the project. Now project activities are being implemented smoothly. We believe that it will move even more smoothly next year. What opportunities for training and professional development has the project provided?Two graduate students and one post-doctoral research associate are being trained in organic plant breeding. They are doing a fantastic job making wonderful progress. Dr. Siddique published a manuscript and is working in his second manuscript now whereas graduate students are implementing their experiments smoothly as per original plan. How have the results been disseminated to communities of interest?One of the graduate students, Anju Pandy, and Post-Doctoral Research Associate Dr. Irfan Siddique presented their research on Tomato Field Day on August 10, 2023, at Mountain Horticultural Crops Research and Extension Center, Mills River, NC. Dr. Panthee, PI of the project, also gave a talk on the tomato variety development program and the status of variety development. Participants were excited to know the statu of all new tomato varieties. Graduate students and post-docs also gave talks in professional meetings (American Society for Horticultural Science, and Amecian Phytopathological Society) about their research findings. It was received very well by the audience. What do you plan to do during the next reporting period to accomplish the goals?We will be able to submit or even publish one of the manuscripts. Currently, we are analyzing the data. It may not take a long time to finish the data analysis. Once it is done, we should be able to prepare the manuscript and submit it for publication. Impacts What was accomplished under these goals? We started screening tomato genotypes for early blight, late blight, and Septoria leaf spot resistance in the greenhouse and under field conditions. A total of 202 genotypes were screened for the above foliar disease resistance by inoculating using an appropriate concentrations of Alternaria and Septoria pathogens. We are also evaluating 40 tomato genotypes out of 202 set of tomato genotypes for its performance. and disease response in two location (MHCREC, Mills River and MRS Waynesville NC). As of now, the trials look excellent. Lines are segregating very well for all three disease, and there are multiple lines with good level of disease resistance. We will have to verify the results next year. We are also growing a mapping population for the identification of QTL associated with EB and SLS resistance. We will do it by bulk-segregant analysis (BSA). For that reason, this population was screened in the greenhouse and two extreme lines (resistanct and susceptible) for EB and SLS are being evaluated under the field conditions. Trials are excellent as of now. We are also collecting isolates of Alternaria and Septoria from conventional and organic farm conditions. While we already sequenced 20 isolates, we will sequence more pathogens once we have more collection. This activity will address the third objective. Publications Type: Journal Articles Status: Published Year Published: 2023 Citation: Adhikari, T.B., Siddique, M.I., Louws, , F.J., Sim, S.C. and Panthee, D.R. (2023). Molecular mapping of quantitative trait loci for resistance to early blight in tomatoes. Frontiers in Plant Science. 14; https://doi.org/10.3389/fpls.2023.1135884. Type: Conference Papers and Presentations Status: Awaiting Publication Year Published: 2023 Citation: Siddique, M.I., Blume, J., Zhang, J., and Panthee, D.R. (2023). Mapping QTL for septoria leaf spot resistance in tomatoes. HortScience, 59: xx-xx. Type: Conference Papers and Presentations Status: Awaiting Publication Year Published: 2023 Citation: Paudel, R., Pandey, A., Panthee, D.R., Halterman, D., Louws, F.J. and Adhikari, T. (2023). Comparative genome analysis of three Alternaria species threatening tomato and potato production in North Carolina and Wisconsin. Phytopathology. Xx: xx-xx. Type: Conference Papers and Presentations Status: Awaiting Publication Year Published: 2023 Citation: Pandey, A., Paudel, R. Adhikari, T. Louws, F. and Panthee, D.R. (2023). Genome-wide association study (GWAS) to discover the novel markers linked to SLS resistance in tomato. Phytopathology. Xx: xx-xx. Type: Conference Papers and Presentations Status: Awaiting Publication Year Published: 2023 Citation: Panthee, D.R. (2023). Improving heat stress tolerance in tomatoes. HortScience, 59: xx-xx. Type: Other Status: Published Year Published: 2023 Citation: Anju Pandey, A., Paudel, R., Adhikari, T., Louws,, F. and Panthee, D.R. (2023). Mapping of resistance genes to Septoria leaf spot in tomato. Tomato Field Day. Aug 11, 2023, Mills River, NC. Type: Other Status: Published Year Published: 2023 Citation: Siddique, I. and Panthee, D.R. (2023). Mapping QTL for Septoria leaf spot resistance in tomato. Tomato Field Day. Aug 11, 2023, Mills River, NC. Type: Other Status: Published Year Published: 2023 Citation: Zhang, J., and Panthee, D.R. (2023). Evaluation of tomato lines for Bacterial diseases. Tomato Field Day. Aug 11, 2023, Mills River, NC. Type: Other Status: Published Year Published: 2023 Citation: Panthee, D.R., Stone, R., Solsbery, H., Zhang, J., and Siddique, I. (2023). Evaluation of tomato hybrids in replicated trials 2023. Tomato Field Day. Aug 11, 2023, Mills River, NC. **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience: Our target audience is tomato growers, particularly organic tomato growers in NC. Our audience is also the seed industry representatives who deliver the technology through seed distribution. We reached out to tomato growers including conventional as well organic growers in North Carolina. We visited growers' fields to monitor the tomato crop, monitor the disease situation, and collect the tomato diseases including early blight (EB) and Septoria leaf spot (SLS)samples. Five talks were delivered on the tomato field day, which was attended by about 300 participants,on various aspects of tomato diseases and breeding programs in the North Carolina tomato breeding program. Changes/Problems: There was not enough certified Organic field to plant the trials consisting of more than 100 lines. We decided to do the seedling screening for both EB as well as SLS instead this year. By doing this, we will have a limited number of lines to evaluate next year under field conditions. What opportunities for training and professional development has the project provided? We hired two graduate students and one post-doc for this project. All of them are doing a very good job. This is a very good opportunity for them as they are learning new professional skills required in the organic toamto industry including resistance breeding, disease management, and interactions with tomato growers. They are enjoying the opportunity. How have the results been disseminated to communities of interest? While the final results of a completed experiment are yet to be published and delivered, preliminary information was presented on tomato field day by making oral presentations. Every speaker was allowed to speak for 10 minutes and describe the project. What do you plan to do during the next reporting period to accomplish the goals?1. Repeat the seedling screening during spring before finalizing the planting list for summer trials. 2. Evaluate tomato lines for fruit quality under organic conditions. This list will come from seedling screening results. 3. Possible launching of grafting studies. 4. Experiment on QTL mapping for EB and SLS resistance. 5. Characterization of isolates of Alternaria, and Septoria. 6. Extension activities including growers' field visits, field days, and talks on field days. **Impacts** What was accomplished under these goals? We started the project and implemented the project activities to achieve the project goals. The following activities were initiated during this reporting period: Objective 1: We started screening more than 100 tomato breeding lines with different genetic backgrounds for early blight (EB), and Septoria leaf spot (SLS) resistance. We optimized the conditions for seedling screening, and these lines were screened at the seedling stage. The main purpose of screening at the seedling stage was to save time. We also tested various concentrations of the pathogens to optimize the screening process. Objective 2: None. Objective 3a: The SLS segregating population was planted in two locations with the objective of determining the inheritance pattern of resistance to the SLS, and mapping the genes/QTL associated with resistance to the SLS. Data recording from these trials is complete now. We still need to analyze the data. Objective 3b: We started collecting isolates of Alternaria, and Septoria from various organic as well as conventional fields of various counties in NC. We have started culturing and purifying the isolates. The process is still ongoing. Objective 4: We made five presentations on Tomato Field Day,three of which were related to organic tomato production or foliar fungal diseases. We also visited organic and conventional tomato growers to monitor the crop status including disease identification, and disease sample collection, and provide any suggestions related to tomato production. **Publications** - Type: Other Status: Published Year Published: 2022 Citation: Pandey, A., Paudel, R., and Panthee, D.R. (2022). Screening tomato lines for foliar fungal disease resistance. Tomato Field Day. Aug 11, 2022, Mills River, NC. - Type: Other Status: Published Year Published: 2022 Citation: Paudel, R., Pandey, A., Panthee, D.R. (2022). Disease identification and management practices for foliar fungal diseases. Tomato Field Day. Aug 11, 2022, Mills River, NC. - Type: Other Status: Published Year Published: 2022 Citation: Siddique, M.I., Blume, J., Paudel, R., Pandey, A. and Panthee, D.R. (2022). Breeding tomato for Septoria leaf spot resistance. Tomato Field Day. Aug 11, 2022, Mills River, NC. - Type: Other Status: Published Year Published: 2022 Citation: Zhang, J., and Panthee, D.R. (2022). Evaluation of tomato breeding lines for Bacterial speck, and Bacterial spot disease resistance. Tomato Field Day. Aug 11, 2022, Mills River, NC. - Type: Other Status: Published Year Published: 2022 Citation: Panthee, D.R., and Zhang, J. (2022). Evaluation of tomato hybrids in replicated trials 2022. Tomato Field Day. Aug 11, 2022, Mills River, NC.

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Furthering the Development of Sprout Inhibitors and Growth Suppressants for Organic Potato

Accession No.	1027247
Project No.	ORE01009
Agency	NIFA ORE\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2021-51106-35584
Proposal No.	2021-04812
Start Date	01 SEP 2021
Term Date	31 AUG 2025
Grant Amount	$595,000
Grant Year	2021
Investigator(s)	Jeliazkov, V.; Stevens, JA, FR.

NON-TECHNICAL SUMMARY

This project will address an important industry issue related to organic potato storage and control of premature sprouting. We hypothesized that plant natural products such as essential oils (EO), EO fractions, blends, and individual compounds can be discovered that will have greater sprout suppression activity compared with the currently used sprout suppressors/inhibitors in organic potato. The long-term goal is to develop potato sprout suppression/inhibitor product(s) for organic potato. The objectives are: (1) Screening of \~ 300 EO and EO fractions and identify ones with the highest potato sprout suppression; (2) Bioassay-guided fractionation of selected EO and EO fractions; (3) Compare the most promising compounds and combinations against currently used sprout inhibitors; (4) Reveal the mode of action of the promising compounds and blends on potato tubers by employing transcription profiling and metabolomics approaches; (5) Communicate the results to the potato industry, scientists, extension, students, and general public. Incorporate the information into online undergraduate and graduate certificates in Organic Agriculture to reach out to students across the nation. The project goal and objectives are in line with the FY 2021 Priority Areas, specifically Priority 3: \"Develop cultural practices and other allowable alternatives..\" and Priority 4: \"Overcome barriers to organic transition\". The project will address limitations in organic potato storage and sprout control that also hinders transition of conventional potato producers to certified organic. The results will facilitate the development of new potato sprout suppressors or inhibitors, improve the quality of potato, reduce environmental impact, and contribute to improved human health.

OBJECTIVES

The goal is to discover essential oil (EO) fractions, blends, and individual compounds that will have greater sprout suppression activity compared with the currently used potato sprout suppressors or inhibitors. The long-term goal is to develop potato sprout suppression/inhibitor product(s) to be used for extending dormancy and/or suppression of premature sprouting in transitional and certified organic potato production. This will overcome one of the major barriers to organic transition faced by potato growers. The development of new sprout suppressors for organic potato will improve the quality of potato and reduce waste from storage, reduce the environmental impact of chemical inhibitors, and contribute to improved human health. The project is based on discussions with potato growers, and will have positive impact on transitional and certified organic production, will improve access to additional markets and consumer groups, and it will increase the competitiveness of the U.S. potato industry.The objectives are: (1) Screening of \~ 300 EO and EO fractions and identify ones with the highest potato sprout suppression; (2) Bioassay-guided fractionation of selected EO and EO fractions; (3) Compare the most promising compounds and combinations against currently used sprout inhibitors; (4) Reveal the mode of action of the promising compounds and blends on potato tubers by employing transcription profiling and metabolomics approaches; (5) Communicate the results to the potato industry, scientists, extension, students, and general public. Incorporate the information into online undergraduate and graduate certificates in Organic Agriculture to reach out to students across the nation.

APPROACH

Objective 1: Screening of 300 natural products (EO, EO fractions, hydrosols, and extracts) that were not tested previously, and identify ones with the highest potato sprout suppression for further bioassay-guided fractionation.Phase 1. Screening of essential oils (EO) and EO fractions in 15-L containersPhase 1.1. First group of controlled environment experiments: Two potato varieties representing fresh market & processing will be used for this group of experiments. A detailed screening of around 300 EOs and EO fractions will be conducted in 15-L containers. A randomized complete design with three replications will be used to evaluate sprouting. Water, Biox (clove oil) and Biox-M (spearmint oil) will be used as controls in all experiments. Measurements of sprouts will be taken after 15, 30, and 45 days.Phase 1.2. Second group of controlled environment experiments: The EO that showed potential as sprout inhibitors will be fractioned (in 4-5 distillation fractions per EO) in Dr. Jeliazkov\'s laboratory at OSU. Both the EO and the EO fractions will be analyzed for chemical profile using Gas chromatography/Mass spectroscopy (GC/MS) by Dr. Charles L. Cantrell at the National Center for Natural Products Research at the University of Mississippi. We will be using the same controls, water, Biox, and Biox-M and the same method outlined in Phase 1.1.Phase 1.3. Third group of controlled environment experiments: The most effective EO, EO fractions, and pure compounds for suppressing sprouting from the previous groups of experiments will be evaluated at different concentrations and duration will be studied by applying selected oils every 15 or 30 days in storage by using wick application. In addition, the selected EO and EO fractions will be tested at T of 8 °C. Statistical regression models will be developed that may predict the best concentration and duration of treatments for the selected oils and compounds.Microscopy analyses of the tuber sprouts to test the hypothesis that most (but not all) EOs (1) may induce necrosis of the meristematic cells but not on the potato periderm; and (2) may break the apical dominance and induce axillary bud sprouting. Tubers from the most contrasting treatments will be examined under light and Scanning Electron Microscopes (SEM) in order to determine if the observed effects are due to physical damage of potato sprouts.Objective 2: Bioassay-guided fractionation of the EOs and EO fractions generated in activities outlined in Objective 1.Bioassay screening results will always dictate the progression of which EO to evaluate and/or which fraction to use for continuation of purification. In general, the most biologically active EO\'s will be chosen for fractionation. Once fractions are generated, biological evaluation will be repeated.Objective 3: Compare the most promising natural product combinations against Biox® and Chlorpropham (CIPC) in a semi-commercial facility.This will screen the most promising EO, EO fractions and pure compounds in 55-gallon (200-L) semi-commercial vessels.Objective 4: Studies to reveal the mode of action of the identified most promising EOs on potato tubers. Integration of state-of-the art methodologies to determine effects of exogenous treatments that alter natural dormancy progression can help identify critical molecular, biochemical and physiological mechanisms, and ultimately, pinpoint the regulatory genes and pathways that can be used as novel targets for manipulation of tuber dormancy more efficiently. Transcriptome Profiling: Tubers will be used to collect samples (i.e., primary buds) during postharvest storage (at different time points following the treatments). Each sample will contain 50-100 buds. RNA will be extracted from isolated meristems using a commercial kit (e.g., Qiagen, RNeasy Plant Mini Kit) for all treatments, biological replicates and time points. RNA concentration and quality will be quantified spectrophotometrically, and RNA integrity will be determined with an Agilent Technologies 2100 Bioanalyzer. Libraries of cDNAs (Illumina) will be generated from RNA samples and sequenced. RNA-seq data will be processed and mapped to the reference potato genome. Differentially expressed genes will be identified and classified by function, and overrepresented ontologies among biological pathways and molecular mechanisms will be identified (e.g., gene-set enrichment and sub-network enrichment analyses). RNAseq results will be confirmed by RT-PCR to quantify transcript abundance of a subset of genes. Targeted metabolomics analysis of plant growth hormones. This will be conducted in the Co-PI Dr. Fred Stevens\' laboratory at OSU. We will apply ultra-performance liquid chromatography (UPLC) with triple-quadrupole linear ion trap mass spectrometry for their analysis. We will detect and quantify growth hormones on a Sciex 4000 QTrap instrument using a selected reaction monitoring (SRM) method developed in Dr. Stevens\' laboratory. Our current panel of plant hormones includes abscisic acid (+/-ABA), ABA-glucopyranosyl ester, dihydrophaseic acid, phaseic acid, neophaseic acid, 7\'-hydroxy-ABA, indole-3-acetic acid (IAA), IAA-alanine, IAA-aspartate, IAA methyl ester, (cis/trans)-zeatin, (cis/trans)-zeatin riboside, dihydrozeatin (DZ), DZ riboside, isopentenyladenine, isopentenyladenosine, and several gibberellins (GA1, GA3, GA4, and GA7).Untargeted metabolomics analysis of plant tissues. The acidified water-methanol extracts will also be analyzed on our untargeted plant metabolomics platform consisting of a UPLC quadrupole Time-of-Flight mass spectrometry system (Sciex 5600 QToF MS/MS) to semi-quantify secondary metabolites, such as steroidal alkaloids and their glycosides.Objective 5: Extension and Education: Communicate the results to the potato industry, scientists, extension, and general public. Incorporate the information from this project into online courses of the OSU online undergraduate and graduate certificates in Organic Agriculture.The results from this project will be disseminated through (1) two factsheets, (2) a recorded webinar for eOrganic, (3) an article at eOrganic, (4) a project website, (5) at growers meetings, and field days, (6) articles in scientific journals, (7) incorporating the new knowledge in two Online Certificates on Organic Farming at OSU. Project participants will be presenting at OR Potato Growers meetings and at the potato field days every year. As part of the potato field days at the OSU HAREC, we will be offering a short workshop on potato sprout control using natural products. To reach out to growers, processors, and general public, the project participants will develop and record a webinar. The recorded webinar will be archived on eOrganic (https://eorganic.info/) website and on the eOrganic YouTube channel at https://www.youtube.com/eorganic . We discussed it with Alice Formiga (eOrganic director), Horticulture Dep. at OSU, and she will be helping with seminar presentation and posting on eOrganic. A link to the recorded webinar will be provided from the website of OR Potato Commission (https://www.oregonspuds.com/)In addition, the results will be compiled in at least 3 manuscripts and published in refereed scientific journals.The results will be included in teaching materials for OSU face to face and online courses. OSU has recently launched an Undergraduate Certificate in Organic Farming, and an Online Graduate Certificate in Organic Agriculture. The knowledge gained within this project will be incorporated in online courses in the Organic Certificates to reach students and professionals across the nation. Progress 09/01/23 to 08/31/24 Outputs Target Audience:We actively engaged with potato growers by delivering a presentation at the Hermiston Farm Fair in December 2023, reaching an audience of approximately 110 participants. Beyond this, my graduate students and I shared our research findings at prestigious international conferences, attracting a diverse audience of professionals, extension agents, and researchers from around the world. These events served as valuable platforms to disseminate our work, facilitate meaningful discussions, and foster collaborations within the broader agricultural community, further enhancing the impact and relevance of our research. Below please find the exact presentations. The graduate student names are noted with asterisk: Conference presentations Almutairi*, H., V.D. Zheljazkov, and C.L. Cantrell. 2023. Essential Oils for Potato (Solanum tuberosum L.) Sprout Suppression at Room Temperature. Association for the Advancement of Industrial Crops, (AAIC)-2023, 34th Annual Meeting, Aug 27-30th, Corvallis, OR, USA. Approximately 60 participants. https://aaic.org/2023-annual-meeting/ Alzarqaa*, A. and V.D. Zheljazkov. 2023. Efficacy of Essential Oils in Suppressing Potato (Solanum tuberosum L.) Sprouting. Association for the Advancement of Industrial Crops, (AAIC)-2023, 34th Annual Meeting, Aug 27-30th, Corvallis, OR, USA. Approximately 60 participants. https://aaic.org/2023-annual-meeting/ Jeliazkov, V.D. 2023. Essentail oils for potato sprout control. Hermiston Farm Fair, Dec 2023, in Hermiston, Oregon.https://www.owgl.org/events/2023/the-50th-hermiston-farm-fair-seminars? Scientific journal publications Alzarqaa, A., T. Astatkie, C.L. Cantrell, V.D. Zheljazkov. 2024. Efficacy of essential oils in suppressing potato sprouting. Industrial Crops and Products, 222, Part 1 https://doi.org/10.1016/j.indcrop.2024.119561 Mukhlid, H., C.L. Cantrell, V.D. Zheljazkov. 2024. Do essential oils suppress potato sprout growth? Industrial Crops and Products 219, 119081 https://doi.org/10.1016/j.indcrop.2024.119081 Changes/Problems:We do not anticipate any major challenges. What opportunities for training and professional development has the project provided?The project significantly enriched graduate students\' and participants\' understanding of potato sprout control through hands-on research and practical application. Graduate students gained invaluable experience in data analysis, synthesizing their findings into manuscripts for publication. This process not only expanded their technical expertise but also provided essential training in scientific writing, critical thinking, and effective communication. By engaging in these activities, students developed the skills necessary for presenting their work to diverse audiences and navigating the demands of professional research environments, thereby enhancing their readiness for future academic and industry careers. How have the results been disseminated to communities of interest?We have actively shared our research on potato sprout control with growers, industry experts, and the broader agricultural community. In December 2023, we presented our findings at the Hermiston Farm Fair, engaging with over 120 attendees. This event provided an excellent opportunity to connect directly with growers and stakeholders who can apply our research in practical ways. Our efforts have also extended to the international stage. My graduate students and I presented at several prominent conferences, where we connected with professionals, extension agents, and researchers from around the world. These interactions not only allowed us to share our discoveries but also facilitated meaningful discussions, sparking new ideas and collaborations within the agricultural community. Below is a summary of our presentations (graduate student names are marked with an asterisk): Conference presentations Almutairi*, H., V.D. Zheljazkov, and C.L. Cantrell. 2023. Essential Oils for Potato (Solanum tuberosum L.) Sprout Suppression at Room Temperature. Association for the Advancement of Industrial Crops, (AAIC)-2023, 34th Annual Meeting, Aug 27-30th, Corvallis, OR, USA. Approximately 60 participants. https://aaic.org/2023-annual-meeting/ Alzarqaa*, A. and V.D. Zheljazkov. 2023. Efficacy of Essential Oils in Suppressing Potato (Solanum tuberosum L.) Sprouting. Association for the Advancement of Industrial Crops, (AAIC)-2023, 34th Annual Meeting, Aug 27-30th, Corvallis, OR, USA.

Approximately 60 participants. https://aaic.org/2023-annual-meeting/ Jeliazkov, V.D. 2023. Essentail oils for potato sprout control. Hermiston Farm Fair, Dec 2023, in Hermiston, Oregon.https://www.owgl.org/events/2023/the-50th-hermiston-farm-fair-seminars? Scientific journal publications Alzarqaa, A., T. Astatkie, C.L. Cantrell, V.D. Zheljazkov. 2024. Efficacy of essential oils in suppressing potato sprouting. Industrial Crops and Products, 222, Part 1https://doi.org/10.1016/j.indcrop.2024.119561 Mukhlid, H., C.L. Cantrell, V.D. Zheljazkov. 2024. Do essential oils suppress potato sprout growth? Industrial Crops and Products 219, 119081https://doi.org/10.1016/j.indcrop.2024.119081 What do you plan to do during the next reporting period to accomplish the goals? Ongoing Analysis: Continue analyzing potato tissue samples using HPLC/MS to monitor plant hormones, glucose, and abscisic acid levels. Evaluate the impact of essential oil treatments on these parameters and their relationship to changes in potato quality. Chemical Profiling: Conduct detailed chemical profiling of the most effective essential oils identified during the project. Focus on optimizing their use for enhanced potato sprout control and shelf-life extension. Fractionation and Compound Identification: Perform fractionation of the top-performing essential oils to isolate and identify active fractions and compounds, paving the way for the development of innovative, targeted sprout control products. Controlled Environment Studies: Establish additional controlled environment experiments to further test and refine the efficacy of essential oil treatments under variable storage conditions. Essential Oil Fraction and Blend Studies: Expand research on essential oil fractions and blends to identify optimal combinations and formulations for maximum sprout control effectiveness. Outreach and Presentations: Present key findings and practical insights at the Hermiston Farm Fair, engaging growers and industry stakeholders in meaningful discussions. Industry Collaboration: Strengthen the ongoing partnership with the 1,4 Group, leveraging their facilities in Meridian, Idaho, to advance research and application of essential oil treatments. Publications: Compile project findings into manuscripts for submission to 1-2 peer-reviewed journals in 2024-2025, disseminating results to the broader scientific and agricultural communities. Impacts What was accomplished under these goals? · Completed chemical analyses of some of the essential oils · Completed analysis of potato tissue samples for sugars using NMR for some of the experiments. · Analyzed the chemical profile of the most effective essential oils identified in some of the experiments. · Set up and conducted follow-up controlled environment experiments with the most effective essential oils discovered so far. ·Presented findings at the Hermiston Farm Fair on December 2023. · Graduate students presented seminars on their research progress and findings. · Graduate students presented at international meeting · Held a collaborative meeting with the 1,4 Group to explore joint efforts in developing alternative sprout control products for potatoes. · Compiled project results into two refereed journal publications submitted in 2023. Publications Type: Peer Reviewed Journal Articles Status: Published Year Published: 2024 Citation: Alzarqaa, A., T. Astatkie, C.L. Cantrell, V.D. Zheljazkov. 2024. Efficacy of essential oils in suppressing potato sprouting. Industrial Crops and Products, 222, Part 1 https://doi.org/10.1016/j.indcrop.2024.119561 Type: Peer Reviewed Journal Articles Status: Published Year Published: 2024 Citation: Mukhlid, H., C.L. Cantrell, V.D. Zheljazkov. 2024. Do essential oils suppress potato sprout growth? Industrial Crops and Products 219, 119081 https://doi.org/10.1016/j.indcrop.2024.119081 Progress 09/01/22 to 08/31/23 Outputs Target Audience:We engaged with potato growers through a presentation at the Hermiston Farm Fair in December 2022, reaching approximately 150 participants, as well as with members of the Oregon Potato Commission in March 2022. Additionally, my graduate students and I presented our findings at various international conferences, attended by a diverse audience of professionals, extension agents, and researchers. These events provided valuable opportunities to share our work and foster discussions within the broader agricultural community. Below please find the exact presentations. The graduate student names are noted with asterisk: Jeliazkov (Zheljazkov), V.D. and J. Thoma*. 2022. Title: The promise of essentials oils as sprout suppressants in potato storage and as alternatives to synthetic pesticides. The 49th Hermiston Farm Fair Seminars, Nov 30 - Dec 2, 2022. Invited presentation, approximately 150 participants. https://agsci.oregonstate.edu/harec/farm-fair Jeliazkov (Zheljazkov), V.D. 2022. Title: Plant natural products as sprout inhibitors or growth suppressants in potatoes. Presented at the Oregon Potato Commission Meeting, March 3, 2022. Approximately 15 participants. Zheljazkov, V.D. Invited presentation. 2023. Essential Oils for Sprout Control in Potato. 5th International Conference on Natural Products Utilization: from Plants to Pharmacy Shelf (ICNPU-2023, May 30-02 June 2023, Sts. Constantine and Helena Resort, Bulgaria. Approximately 180 participants. https://icnpu2023.com/ Almutairi*, H., V.D. Zheljazkov, and C.L. Cantrell. 2023. Essential Oils for Potato (Solanum tuberosumL.) Sprout Suppression at Room Temperature.Association for the Advancement of Industrial Crops, (AAIC)-2023, 34thAnnual Meeting, Aug 27-30th, Corvallis, OR, USA. Approximately 60 participants. https://aaic.org/2023-annual-meeting/ Alzarqaa*, A. and V.D. Zheljazkov. 2023. Efficacy of Essential Oils in Suppressing Potato (Solanum tuberosumL.) Sprouting. Association for the Advancement of Industrial Crops, (AAIC)-2023, 34thAnnual Meeting, Aug 27-30th, Corvallis, OR, USA. Approximately 60 participants. https://aaic.org/2023-annual-meeting/ Changes/Problems:We do not anticipate any major challenges. What opportunities for training and professional development has the project provided?The project enhanced graduate students\' and participants\' understanding of potato sprout control through hands-on research and practical application. Graduate students gained valuable experience in data analysis and scientific communication by compiling their findings into a manuscript for publication. This process not only deepened their technical expertise but also provided critical training in scientific writing and presentation, equipping them with skills essential for their professional development. How have the results been disseminated to communities of interest?We\'ve been actively sharing our research on potato sprout control with growers and industry experts. In December 2022, we presented our work at the Hermiston Farm Fair, connecting with about 150 attendees, and then in March 2022, we engaged with members of the Oregon Potato Commission. These events allowed us to bring our findings directly to the people who could benefit most. We\'ve also taken our research to the international stage. My graduate students and I presented at several major conferences, where we connected with professionals, extension agents, and researchers from around the world. These interactions not only let us share our discoveries but also sparked valuable discussions within the agricultural community. Here\'s a rundown of our presentations (graduate student names are marked with an asterisk): Jeliazkov (Zheljazkov), V.D. and J. Thoma*. 2022. The promise of essential oils as sprout suppressants in potato storage and as alternatives to synthetic pesticides. Presented at the 49th Hermiston Farm Fair Seminars, Nov 30 - Dec 2, 2022, reaching about 150 participants. Hermiston Farm Fair Jeliazkov (Zheljazkov), V.D. 2022. Plant natural products as sprout inhibitors or growth suppressants in potatoes. Shared at the Oregon Potato Commission Meeting on March 3, 2022, with around 15 attendees. Zheljazkov, V.D. 2023. Essential Oils for Sprout Control in Potato. Delivered at the 5th International Conference on Natural Products Utilization in Bulgaria, May 30 - June 2, 2023, to an audience of roughly 180 participants. ICNPU-2023 Almutairi, H., V.D. Zheljazkov, and C.L. Cantrell*. 2023. Essential Oils for Potato (Solanum tuberosum L.) Sprout Suppression at Room Temperature. Presented at the AAIC-2023, 34th Annual Meeting, Aug 27-30, in Corvallis, OR, to around 60 participants. AAIC-2023 Alzarqaa, A. and V.D. Zheljazkov*. 2023. Efficacy of Essential Oils in Suppressing Potato (Solanum tuberosum L.) Sprouting. Also presented at the AAIC-2023, with about 60 attendees. AAIC-2023 Through these events, we\'ve been able to share our work with a diverse audience and engage in discussions that will help shape the future of sustainable sprout control in potato storage. What do you plan to do during the next reporting period to accomplish the goals?· Ongoing Analysis: Continue analyzing potato tissue samples using HPLC/MS to monitor plant hormones, glucose, and abscisic acid levels, evaluating changes in potato quality under essential oil treatments. · Chemical Profiling: Further analyze the chemical profiles of the most effective essential oils identified in the project, focusing on optimizing their use in potato sprout control. · Fractionation and Compound Identification: Conduct fractionation of the most effective essential oils to isolate specific fractions and compounds, paving the way for new product development. · Controlled Environment Studies: Set up additional controlled environment experiments to further test and refine the most effective essential oil treatments identified to date. · Essential Oil Fraction and Blend Studies: Expand studies on essential oil fractions and blends to determine optimal combinations for sprout control efficacy. · Outreach and Presentations: Present findings at the Hermiston Farm Fair. · Industry Collaboration: Continue the collaborative work with the 1,4 Group utilizing their facilities in Meridian, Idaho · Publications: Compile and prepare project findings for submission, targeting 1-2 refereed journal publications in 2023-2024. Impacts What was accomplished under these goals? ·Completed analysis of potato tissue samples for sugars using NMR for some of the experiments. · Analyzed the chemical profile of the most effective essential oils identified in some of the experiments. · Set up and conducted follow-up controlled environment experiments with the most effective essential oils discovered so far. · Conducted detailed studies on essential oil fractions and blends for their effectiveness. · Presented findings at the Hermiston Farm Fair on December 2, 2022. · Graduate students presented seminars on their research progress and findings. · Successfully defended MS thesis by Jena Thoma, a graduate student contributing to this project. · Held a collaborative meeting with the 1,4 Group to explore joint efforts in developing alternative sprout control products for potatoes. · Compiled project results into two refereed journal publications submitted in 2023. Publications Type: Peer Reviewed Journal Articles Status: Published Year Published: 2023 Citation: 0000-0002-3479-9653 Thoma JL, Cantrell CL, Tamang P and Zheljazkov VD (2023) Determining the optimum mixture of three essential oils for potato sprout suppression at room temperature storage. Front. Plant Sci. 14:1199117. doi: 10.3389/fpls.2023.1199117 **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience:Target audiences include researchers, graduate students, extension agents, growers, processors, other agricultural professionals, and general public. Efforts: We have been in contact with Oregon Potato Association and presented at the meeting at the Oregon Potato Commission. Also, our extension efforts include the current development of extension publication, development of an webinar to be presented at eOrganic, and presentation at international conference. In addition, we shared the research results so far with the scientific community and graduate students by 4 refereed journal publications. Refereed journal publications: Zheljazkov, V.D., G. Micalizzi, S. Yilma, C.L. Cantrell, A. Reichley, L. Mondello, I.B. Semerdjieva, and T. Radoukova. 2022. Melissa officinalis L. as a Sprout Suppressor in Solanum tuberosum L. and an Alternative to Synthetic Pesticides. J. Agric. Food Chem. 2022, 70, 44, 14205-14219 https://doi.org/10.1021/acs.jafc.2c05942 Impact factor (IF): 5.8 Thoma, J.L.; Cantrell, C.L.; Zheljazkov, V.D. 2022. Effects of Essential Oil Fumigation on Potato Sprouting at Room-Temperature Storage. Plants 2022, 11, 3109. https://doi.org/10.3390/plants11223109 IF: 4.65 Thoma, J.L.; Cantrell, C.L.; Zheljazkov, V.D. 2022. Evaluation of Essential Oils as Sprout Suppressants for Potato (Solanum tuberosum) at Room Temperature Storage. Plants, 11, 3055. https://doi.org/10.3390/plants11223055 IF: 4.65 Thoma, J.;

Zheljazkov, V.D. 2022. Sprout Suppressants in Potato Storage: Conventional Options and Promising Essential Oils\--A Review. Sustainability 2022, 14, 6382. https://doi.org/10.3390/su14116382 Impact Factor: 4.08 ?Conference presentations Zheljazkov, V.D., G. Micalizzi, S. Yilma, L. Mondello, and C.L. Cantrell. 2021. Essential oils as sprout inhibitors in potato. Oral presentation. Symposium \"Hemp, Medicinal and Aromatic Crops: Production, Phytochemistry, & Utilization\" American Chemical Society, ACS 2021 Fall Meeting. Atlanta, GA; August, 22-26, 2021 Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?Jeliazkov, the PI of the project hired four graduate students that are being trained and conduct research on the project goals and objectives. All of the students are minorities, and 3 are international. Three of the students have stipends from the Saudi Arabia government. These include: Name PhD/MS Title Current position Luluh Nasser A Aljayan MS Natural products for potato sprout control MS Jena Thoma MS Essential oils as sprout inhibitors for potato MS Hanin Mukhlid M Almutairi PhD Studies on essential oils as sprout inhibitors in potato (tentative) PhD student Areej Abdulah A. Alzarqaa PhD Screening of natural products for sprout control in potato (tentative) PhD student How have the results been disseminated to communities of interest?As indicted in the previous sections, our group already published 4 refereed journal papers in 2022. These are reaching researchers, graduate students, and extension agents across the country and internationally. In addition, we are reaching out to growers, e.g. with a presentation at the Oregon Potato Commission Meeting in March, 2022. What do you plan to do during the next reporting period to accomplish the goals?The four graduate students, I, and the other project participants will continue with the research work as outlined in the project proposal to meet the objectives. These include the following activities: Continue with the analyses of potato tissue samples using HPLC/MS for plant hormones and glucose and abscisic acid kits to evaluate potato quality changes as a function of the essential oil treatments Continue with the analyses of chemical profile of the most effective essential oils identified in this project so far Fractionation work on the most effective essential oils to identify fractions and individual compounds (molecules) that can be used for new product development Continue with setting up follow up controlled environment experiments with the most effective essential oils identified so far Essential oil fractions and blends studies Presentation at the 2022 Hermiston Farm Fair on Dec 2, 2022 Seminar presentations of the graduate students on their research Defense of MS thesis by Jena Thoma, graduate student working on this project Meeting with 1,4 group that is developing alternative sprout control products for potato to develop collaborative efforts for new product development Compile our results so far into 2-5 refereed journal publications in 2023 Develop an Extension publication Present a Webinar for eOrganic **Impacts** What was accomplished under these goals? First, we did a very detailed literature search and compiled the information into a review paper. This review presented an overview of physical and chemical means of sprout suppression in stored potato and critically analyzed studies focusing on the use of essential oils (EOs) for sprout suppression. Challenges and limitations of EO use in potato sprout suppression are discussed as well as areas of future research. The review was published in Sustainability in 2022. We conducted around 20 different controlled environment experiments so far to meet the objectives. We did fractionation of one of the most promising essential oils (EO) from the first two experiments, tested these fractions, and individual pure compounds found in these fractions. The EOs of interest were analyzed using gas chromatography coupled to mass spectrometry (GC-MS) and/or a flame ionization detector (GC-FID); the detailed chemical profiles was provided. The Melissa officinalis EO was fractionated into 7 fractions and these were tested on minitubers. We identified two fractions (F and A) that suppressed potato sprouting better than the whole oil. The GC-MS-FID analyses of M. officinalis EO fraction A identified myrcene, Z-ocimene, E-ocimene, trans-caryophyllene, and α-humulene as the main constituents, while the main constituents of fraction F were α-terpineol, β-citronellol, and geraniol. The pure isolated compounds, together with the major compound in M. officinalis EO (citral), were tested for sprout suppression on 3 potato cultivars (Ranger Russet, Terra Rosa, and Dakota TrailBlazer), which revealed that β-citronellol reduced the sprout length and the number of sprouts in all 3 cultivars, while citral and (+)-α-terpineol) reduced the sprout length in all 3 cultivars and the number of sprouts in Ranger Russet relative to the two controls. Myrcene had stimulating effect on the number of sprouts in Terra Rosa. However, none of the pure compounds suppressed sprouting completely or comparable to the EO of M. officinalis. In one of the graduate student experiments, we evaluated twenty-one essential oils (EOs) as potential sprout suppressants in cv. Ranger Russet potatoes at room-temperature storage. Treatment with Artemisia herba-alba EO was the most effective at suppressing both sprout length and sprout number over a 90-day storage period. GC\--MS\--FID analysis of A. herba-alba EO revealed the presence of α-thujone, hexadecenoic acid, β-thujone, camphor, sabinene, and camphene at amounts >1%. Other plants such as Cistus ladanifer, Ocimum basilicum, Ormenis mixta, and Salvia sclarea EOs significantly reduced sprout length for shorter storage periods, whereas Cinnamomum zeylanicum (bark) and Laurus nobilis EOs also significantly reduced sprout number. Syzygium aromaticum (clove) EO did not significantly suppress sprouting at room temperature. These results indicate the potential of certain EOs to be used as sprout suppressants for room-temperature potato storage, providing needed alternatives for both organic and conventional potato industries. The findings were compiled into a manuscript and published in the journal Plants in 2022. Yet, in another graduate student experiment, we evaluated the potential of ten EOs for sprout suppression in potato cultivar Ranger Russet at room temperature. Treatment with Cymbopogon citratus EO was found to be the most effective sprout suppressant, completely suppressing sprouting over the 90-day storage period. The EOs of Myrtus communis and Melaleuca quinquenervia significantly reduced sprout length relative to the control but did not have any effect on sprout number. The findings were compiled into a manuscript and published in Plants in 2022. **Publications** - Type: Journal Articles Status: Published Year Published: 2022 Citation: Thoma, J.L.; Cantrell, C.L.; Zheljazkov, V.D. 2022. Effects of Essential Oil Fumigation on Potato Sprouting at Room-Temperature Storage. Plants 2022, 11, 3109. https://doi.org/10.3390/plants11223109 Impact Factor: 4.65 - Type: Journal Articles Status: Published Year Published: 2022 Citation: Zheljazkov, V.D., G. Micalizzi, S. Yilma, C.L. Cantrell, A. Reichley, L. Mondello, I.B. Semerdjieva, and T. Radoukova. 2022. Melissa officinalis L. as a Sprout Suppressor in Solanum tuberosum L. and an Alternative to Synthetic Pesticides. J. Agric. Food Chem. 2022, 70, 44, 1420514219 https://doi.org/10.1021/acs.jafc.2c05942 Impact factor (IF): 5.8 - Type: Journal Articles Status: Published Year Published: 2022 Citation: Thoma, J.L.; Cantrell, C.L.; Zheljazkov, V.D. 2022. Evaluation of Essential Oils as Sprout Suppressants for Potato (Solanum tuberosum) at Room Temperature Storage. Plants, 11, 3055. https://doi.org/10.3390/plants11223055 IF: 4.65 - Type: Journal Articles Status: Published Year Published: 2022 Citation: Thoma, J.; Zheljazkov, V.D. 2022. Sprout Suppressants in Potato Storage: Conventional Options and Promising Essential OilsA Review. Sustainability 2022, 14, 6382. https://doi.org/10.3390/su14116382 Impact Factor: 4.08

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Kale Alternatives Leading to Enhanced Economics (kale): Improving Profitability and Evaluating Marketing Decisions of Organic Kale Farmers Facing Alternaria Leaf Spot in the Southeastern U.s.

Accession No.	1027130
Project No.	SC-2021-04819
Agency	NIFA SC.\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2021-51106-35495
Proposal No.	2021-04819
Start Date	01 SEP 2021
Term Date	31 AUG 2024
Grant Amount	$500,000
Grant Year	2021
Investigator(s)	de Figueiredo Silva, F.; Keinath, AN, P..; Meadows, IN, .; Vassalos, MI, .; Turner, AA, .; Ballew, JU, .

NON-TECHNICAL SUMMARY

Kale (Brassica oleracea L. var. acephala) has been a popular and nutritious leafy green for over a decade in the United States. However, U.S. organic kale producers face losses due to Alternaria leaf spot, also known as black spot, resulting in decreased sales and consumption, generating economic losses to the marketing outlets (distributors) and growers. A rough estimate of economic losses due to Alternaria leaf spot is \$14.4 million dollars per year in United States. The overall goal of this project is to accurately estimate the economic losses due to Alternaria leaf spot in organic kale production, based on precise predictions of disease incidence, and to educate organic kale farmers how to improve organic disease management and marketability of the product. This project has four specific objectives that span production, economics, extension and education: (i) identify best integrated practices (biopesticides, cultivars, plant and row spacing, cover crops, and post-harvest handling); (ii) estimate growers\' profitability, investigate their marketing decisions, and identify consumer preferences; (iii) disseminate research outcomes via field days, grower talks, fact sheets, videos, and enterprise budgets for organic kale; and (iv) prepare current and future agricultural educators to estimate the profitability of organic kale production and how to treat the disease with integrated best practices.

OBJECTIVES

Production Research: Identify the best combination of cultural practices, biopesticides, cultivars and post-harvesting practices to produce organic kale in Southeastern US in the presence of Alternaria leaf spot. Specifically, we seek to: Determine the effectiveness of 6 biopesticides and management practices combined with different cultivars to manage Alternaria leaf spot while maintaining or improving yields relative to the average yields of the cooperating grower (confidential information).Identify the best combinations of practices that effectively manage Alternaria leaf spot in the field. Four experiments will be done in the second and third years at the Clemson University Coastal REC in Charleston, SC. Replicate the 4 treatments identified as the best combinations of practices to effectively manage Alternaria leaf spot in Walter P. Rawl & Sons and in the NCSU research station to identify whether results change with location.Evaluate post-harvest disease development under different storage treatmentsEconomic Research: Analyze the organic kale growers supply chain and estimate growers\' profitability under different scenarios with Alternaria leaf spot. Specifically, we seek toIdentify organic kale growers\' current practices, disease damages, input use, yields, marketing outlets, and supply obstacles. Survey producers in South Carolina and North Carolina (majority of kale producers in the southeastern US) in 2021, 2022 and 2023.Build enterprise budgets for organic and conventional kale considering yields for the different varieties, practices and biopesticides used in objective 1, and compare their profitability given marketing strategies listed in objective 2a to estimate the benefits from transitioning from conventional to organic.Identify consumer preferences for kale labelled as organic and/or locally produced using both online survey instruments and face-to-face interviews in selected direct marketing outlets (based on Figure 1).Identify and delimit state-wide zoning areas where organic kale is profitable using estimates of yield given different management practices combined with geospatial information regarding land use and marketing locations.Extension Outreach: Educate growers on how to best produce organic kale in the presence of Alternaria leaf spot. Specifically, we seek toGenerate fact sheets to disseminate the results of objectives 1 and 2.Generate and provide MS. Excel spreadsheet with parameters from the budgets built in objective 2b.Organize and hold 2 field days in the third year of the project to guide growers through the best management practices identified in the project and present recommendations at vegetable grower meetings.Upload videos to Clemson University - PSA YouTube channel (https://www.youtube.com/user/clemsonpsa) illustrating best practices.Graduate Education: Provide multi-disciplinary experiences for graduate students in applied economics and statistics and plant and environmental sciences. Specifically, we seek toTeach pre-service agricultural educators (senior undergraduate agricultural education students) and secondary in-service agricultural educators (high school teachers) how to read and use budgets, to estimate the profitability of conventional and organic production to identify the benefits of transitioning to organic, identify the disease and treat it with integrated best practices.Provide cross-disciplinary education for graduate students working on the project. Graduate students in applied economics and statistics and plant and environmental science will learn about both the economics of disease control and field experiment design, implementation, and evaluation.

APPROACH

For objective 1, in each year, field experiments will be done in spring and fall on certified organic land at the Clemson University Coastal Research and Education Center (CREC), Charleston, SC by Anthony Keinath (Co-PI), the PES graduate student, and the temporary grant employee. In experiments in which naturally occurring inoculum is used, leaf lesions from one plot of each treatment will be cultured to recover Alternaria spp. A. japonica produces single conidia, whereas A. brassicae produces chains of conidia, so these two species can be identified based on their spores. Identification, for at least one isolate of each cultural type, will be verified with multilocus genotyping based on three diagnostic gene sequences: glyceraldehyde-3-phosphate dehydrogenase (GAPDH), RNA polymerase second largest subunit (RPB2), and translation elongation factor 1-alpha (TEF1) (Woudenberg et al. 2013). Sequences will be compared to reference sequences deposited in GenBank by Woudenberg et al. (2013). In year 1, ten cultivars, two of each of five horticultural types of kale, will be evaluated for incidence and severity of Alternaria leaf spot in repeated greenhouse experiments. Plants will be inoculated as described by Keinath et al. (2021). The least susceptible curly kale cultivar and the least susceptible cultivar among the other four types of kale will be used in field experiments in subsequent years, along with Darkibor as the standard cultivar. Five biopesticides, representing different classes of active ingredients, will be evaluated in repeated greenhouse experiments. Plants will be inoculated as described by Keinath et al. (2021) with A. japonica and A. brassicae in separate experiments. Cultivar Darkibor will be used with four replicate pots of two plants per pot. Disease incidence and severity will be evaluated 2 weeks after inoculation. Two biopesticides that significantly reduce disease compared to the nontreated control and are at least as effective as copper will be tested in field experiments in subsequent years .In year 2, the best practices identified in year 1 experiments will be integrated in a factorial 4 x 3 split-plot design with 4 blocks that includes: 2 biopesticides plus 2 controls (nontreated and copper), whole plot, and 3 cultivars, split plot. Treatments will be applied with a handheld boom and backpack sprayer weekly for 6 weeks starting 3 weeks after transplanting. If disease has not appeared from natural inoculum by 1 week before the first harvest, the end plants of each plot will be inoculated with A. japonica and A. brassicae on opposite plot ends. Alternaria leaf spot will be assessed by visually by estimating incidence, defined as the percentage of plants in a plot with symptoms on one or more leaves staring when symptoms appear.In year three, the best practices from year 2 will be tested in a factorial 2 x 2 design with 3 blocks. Plots will be rated for Alternaria leaf spot once immediately before first harvest and harvested once as described above. Data will be analyzed with an appropriate split-plot model as described above, with season as the whole plot, location as the split-plot, and treatments as split-split plots. We will replicate the experiments at Walter P. Rawl & Sons, Pelion, SC, and the Mountain Research Center, Waynesville, NC. To quantify the potential losses associated with leaf spot development in storage, post-harvest cooling/sanitation methods and storage temperatures will be evaluated in years 2 and 3 by a graduate student. For Objective 2, we will obtain information from kale growers regarding current practices, input use, yield, disease management (including Alternaria leaf spot), marketing decisions and producers\' obstacles in the supply chain of kale. The data required to achieve this goal will be obtained from a survey instrument administered to growers who manage the day-to-day operations of their farms. These surveys will be sent to every farmer in the listserv by Carolina Farm Stewardship Association, that use organic. These surveys will also be sent to certified organic growers listed on the USDA website. The questionnaire will include sections related to: i) demographic characteristics and risk tolerance levels of the producer, ii) agronomic characteristics of the field, iii) operation characteristics iv) the impact of Alternaria leaf spot on production, iv) current management practices, including those done to manage Alternaria leaf spot, v) produce marketing decisions, vi) adoption of organic practices and potential limiting factors towards this goal and vii) obstacles faced while transitioning to organic production. The list of questions will be reviewed with producers and stakeholders.Three more surveys will be utilized to identify consumer preferences toward organic and local produce, specifically kale. We will use focus groups with consumers, industry experts, and extension agents to pretest the questionnaire for wording errors and clarifications prior to the distribution of the survey instrument. At the regional level, an online survey to Southeastern US consumers using Quatrics will be performed to examine the impact of demographic characteristics, lifestyle preferences, and different information outlets on the probability that a consumer buys (or will buy) organic or local produce. We will also estimate consumers\' willingness to pay for organic kale with lesser desirable characteristics using representative photos of the three classes, specifically, with minor leaf spots on the leaves. South Carolina has more than 200 local produce market outlets (SC Dept. Health and Environmental Control). We will survey consumers in selected locations. Graduate students will personally survey consumers.We will use the outcomes of objectives 1 and 2, and geospatial information on land use combined with marketing outlet destinations obtained in survey to determine areas in the state where organic kale is profitable. The graduate student will develop a model that integrates these datasets to identify and delimit state-wide zoning areas where organic kale is profitable. For Object 3, this project will generate peer-reviewed fact sheets published through Land-Grant Press by Clemson Extension that will be distributed in the field days and grower talks. They will summarize the outcomes of our experiments and economic analyses. The enterprise budgets built in objective 2b will be based on the most profitable treatments obtained in the experiment. Budgets will be posted on the Clemson Extension and project websites. In year 3, three field days will be organized to allow growers to see results of the on-farm research. Some of these field days will be recorded and posted online. Specifically, they will present information on how profits change with the use of biopesticides and cultivars, with the adoption of different row and plant spacing, with different post-harvest procedures and with different marketing strategies.For Objective 4, graduate students involved with the estimation of economic losses and experimental procedures will present a workshop in years 2 and 3 of the project to pre-service and secondary in-service agricultural educators in a state-wide professional development workshop to train these educators in how to read and use enterprise budgets - including the MS.Note that due to current (June 2021) COVID-19 restrictions, face-to-face interviews and in-person meetings are not allowed. These interviews and in-person meetings (such as field days and workshop) will occur only in the second and third year of the project. We expect that by the application of the surveys these restrictions will be lifted. If not, surveys of the marketing location managers will be performed seeking to identify marketing practices and meetings will be performed online. Progress 09/01/23 to 08/31/24 Outputs Target Audience:• Organic and conventional kale growers; • Organic and conventional produce growers; • Broad public Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?Trained two graduate students on survey design, implementation and analysis. How have the results been disseminated to communities of interest?Conferences: 2024Agricultural & Applied Economics Association (AAEA)Annual meeting. Extension field day Keinath, A. P. 2023. Biopesticides to Manage Alternaria Leaf Spot on Organic Kale. Grant-supported, on-farm field day, Pelion, SC., November 15, 2023. Attendees: 20. https://www.youtube.com/watch?v=LDoyv-ZOxac) Extension presentations Keinath, A. P. 2024. Managing Black Spot on Kale and Damping-off on Direct Seeded and Transplanted Vegetables. Midlands Vegetable Grower Meeting, Pelion, SC., February 7, 2024. Attendees: 56. Keinath, A. P. 2024. Vegetable Disease Management Update. 2024 Pee Dee Vegetable Production Meeting, Florence, SC., February 29, 2024. Attendees: 70. What do you plan to do during the next reporting period to accomplish the goals? Finalize the in-person interviews at Farmers markets: Advise student on data collection, data management and analysis. Submit two more papers to journals using data from farmers markets and producer survey collected through Qualtrics. Finalize the Profitability analysis using ArcGIS and submit it to publication. Impacts What was accomplished under these goals? 1. Production Research: In fall 2023, two cultivars and various biopesticides were tested on-farm in Lexington, SC, and in research plots in Waynesville, NC, to assess management in two other environments. In both experiments, cultivars Darkibor and Winterbor did not differ, and biopesticides did not differ from the non-treated control. 2. Economic Research Enterprise Budget on conventional and organic kale was published online (https://www.clemson.edu/extension/agribusiness/resources/request-budget.html). Organized Field day at collaborator farmer field. Video of field day on disease management on organic kale was uploaded online (https://youtu.be/LDoyv-ZOxac?si=CPaOPa_OpnlTflTL). Workshop to Agricultural Educators at the South

Carolina Association of Agricultural Educators (SCAAE) at Lexington, SC on July 15th-18th, 2024. A pre- and post-survey on knowledge about Organic was performed and indicated that, intially, ag. educators did not know what the USDA organic label meant (37% partially correctly identified its defintion), but after the workshop, they indicated to know a lot more (96% partiallycorrectly identified its defintion). Publications Type: Journal Articles Status: Accepted Year Published: 2024 Citation: Ureta, Joan, Felipe de Figueiredo Silva, Michael Vassalos and George Strickland. Effects of Organic and Origin Labels on Consumer Willingness to Pay for Kale: A Case Study in Southeastern US. Accepted in Journal of Food Distribution Research. Type: Journal Articles Status: Published Year Published: 2024 Citation: Behler, Shane; Felipe de Figueiredo Silva, Michael Vassalos, and Joan Ureta. Consumer Willingness to Pay for Visually Imperfect Organic Kale. Journal of Agricultural and Applied Economics. Published online 2024:1-25. https://doi.org/10.1017/aae.2023.42 Type: Journal Articles Status: Published Year Published: 2024 Citation: Keinath, A. P. 2024. Microbial and biochemical biofungicides ineffective against Alternaria black spot on organic kale. PhytoFrontiers 4. https://doi.org/10.1094/PHYTOFR-04-24-0039-R Type: Journal Articles Status: Published Year Published: 2024 Citation: Toporek, S. M., Reich, J. N., and Keinath, A. P. 2024. Recovery of Alternaria brassicicola from chopped, bagged kale (Brassica oleracea var. acephala). Plant Dis. 108. https://doi.org/10.1094/PDIS-01-24-0030-SC Type: Conference Papers and Presentations Status: Other Year Published: 2024 Citation: Arnold, Jane, Felipe de Figueiredo Silva and Michael Vassalos. Farmers Markets: How to keep up with the expanding market? 2024 Agricultural & Applied Economics Association (AAEA) Annual Meeting, New Orleans-LA, July/2024. Type: Conference Papers and Presentations Status: Other Year Published: 2024 Citation: Arnold, Jane, Felipe de Figueiredo Silva and Michael Vassalos. Do Farmers Environmental Perspectives Drive their Decision to Transition to Organic Production? 2024 AAEA Annual Meeting, New Orleans-LA, July/2024. Type: Websites Status: Published Year Published: 2024 Citation: Keinath, A. P. 2023. Management of Alternaria Black Spot on Conventional and Organic Kale Grown in the Fall. Clemson IPM Newsletter. Published July 31, 2023. https://blogs.clemson.edu/ipm/management-of-alternaria-black-spot-on-conventional-and-organic-kale-grown-in-the-fall/ Type: Websites Status: Published Year Published: 2024 Citation: Keinath, A. 2024. White Mold on Kale and Other Cool-Season Vegetables. SC Grower blog post, Feb. 13, 2024. https://scgrower.com/2024/02/13/white-mold-on-kale-and-other-cool-season-vegetables/ Progress 09/01/22 to 08/31/23 Outputs Target Audience: Organic and conventional kale growers; Organic and conventional produce growers; Extension agents; Academic community; Broad public. Changes/Problems:Two changes were made to the initial proposal. Both were approved by Drs. Mathieu (Mat) Ngouajio. They are explained below: Producer survey modification: The response rate to the survey distributed via email was very low, probably because of COVID-19, which affected the relationship between extension agents and farmers and farmers behavior towards research and extension activities. This was constraining the ability to make meaningful conclusions. Also because of COVID-19, not all the travel money was used. We requested (and obtained approval) to use part of the travel allowances to pay \$9,9987.75 to Qualtrics to obtain 85 answers to our survey seeking to strengthen our work while not affecting any other portion of the proposed work. Part of the email requesting the modification is copied below. Field experiment in year 3 modification: In years 1 and 2, 6 experiments (4 greenhouse and 2 field) were proposed, but 12 experiments (4 greenhouse and 8 field) were completed. In addition, 28 treatments were proposed and 56 (twice as many) have been evaluated. Both biopesticides and cultivars were evaluated separately in the greenhouse and in the field, plus they were evaluated together in the field in year 2. This shows that the reduced list of biopesticides and cultivars to be evaluated in years 2 and 3 in the field has been already evaluated in years 1 and 2 in the field. None of the biopesticides reduced black spot compared to the nontreated control. Thus, we requested and obtained a protocol modification from Drs. Ngouajio and Smith on 7/19/2023 to forego the field experiments planned for Charleston in year 3. The experiments in Lexington, SC, and Waynesville, NC, for year 3 will be carried out as proposed. Below we attach the entire email sent. Request 1: Producer survey modification We talked during the meeting about a change I\'m having to make in the grant. We promised a producer survey where we would collect info about production practices, barriers to transition, disease management, etc. In the grant, we said that we would distribute the survey to farmers using an email list from Carolinas Farm Stewardship Association and in extension meetings. We are not obtaining a satisfactory response rate, probably because of COVID-19, which have affected the relationship between extension agents and farmers and farmers behavior towards research and extension activities. For that reason, I\'ve talked to Qualtrics to obtain 85 responses on kale producers in the Southeast, including organic farms. The cost is U\$\$ 9,987.75. This survey will allow us to make important conclusions regarding transitioning to organic and disease management. This survey is very important for the grant success given that it will allow the production of extension/education material and help extension agents understanding the producer practices. So it has a big impact on producers in the long-run. The plan is to use money from other accounts that we unexpectedly used less than we promised. For instance, one of the PDs couldn\'t find a master student to work with him on the project due to COVID-19. We also used fewer travel dollars than we expected, also because of COVID-19. Request 2: Field experiment in year 3 modification. The two bullet points and table (in the original request) summarize the experiments proposed when the grant proposal was submitted, and the experiments actually completed after the grant (2021-51106-35495) was awarded in FY 2021. In years 1 and 2, 6 experiments (4 greenhouse and 2 field) were proposed, but 12 experiments (4 greenhouse and 8 field) were completed. In addition, 28 treatments were proposed and 56 (twice as many) have been evaluated. Both biopesticides and cultivars were evaluated separately in the greenhouse and in the field, plus they were evaluated together in the field in year 2. This shows that the reduced list of biopesticides and cultivars to be evaluated in years 2 and 3 in the field has been already evaluated in years 1 and 2 in the field. None of the biopesticides reduced black spot compared to the nontreated control. Thus, we are requesting a protocol modification to forego the field experiments planned for Charleston in year 3. The experiments in Lexington, SC, and Waynesville, NC, for year 3 will be carried out as proposed. Below we discuss each year of the grant in more detail. Year 1 Experiments. The review panel for our previous submission (FY 2020) recommended year 1 screenings be done only in the greenhouse to ensure the results would be completed in time for year 2 field experiments. However, due to the large effect of environmental conditions on plant diseases, especially when there is no known host resistance, we were concerned that greenhouse screening would not give an accurate picture of cultivar tolerance. For example, \"field resistance\" would not be identified in greenhouse screenings. Thus, field screenings of cultivars were added to this year\'s set of experiments. Dr. Anthony Keinath also expanded the cultivar list for the field experiment to 14 cultivars in case any had any resistance. In addition, we wanted an opportunity to compare conventional and organic production, which has rarely been done and seemed appropriate for an Organic Transitions grant, so four cultivar experiments were done in the field, both conventional and organic (in separate fields) in Fall 2021 and Spring 2022. We also believe that the greenhouse screening for biopesticides was not sufficient, based on the extensive literature about environmental effects on plant diseases as well as effects on biopesticides (and conventional pesticides). Thus, most of the biopesticides screened in the greenhouse in separate experiments with the 2 Alternaria species were screened in the field in Fall 2021 and Spring 2022 with both Alternaria species in each experiment. In addition, we screened twice as many biopesticides in the greenhouse as was proposed, based on product labels that included leafy brassica crops, in an attempt to find a product that reduced black spot. No biopesticides in any experiment, greenhouse or field, reduced black spot or increased yields (in the field). Year 2 Experiments. These 2 experiments were carried out exactly as planned. As in the biopesticide experiments, there was no effect of the 3 biopesticides (including copper) on black spot. Some cultivar differences were noted, but as in Year 1, they varied by season and sometimes by species of Alternaria. The field component of this grant has gone significantly beyond the proposed scope of work to determine if any biopesticides are effective against black spot and to determine if there are any consistent differences among cultivars, either more or less susceptible. Harvesting and grading individual kale leaves into healthy and diseased classes requires no less than 6 people for each field experiment: 1 to cut, 3 to sort, 1 to weigh, and 1 to help wherever needed. This additional effort in year 3 will not add any new results to the objective proposed given that the small factorial of biopesticides and cultivars proposed for the last year was already included in the large factorial experiments of the previous years. This modification will not affect the outcome of the project. The proposal anticipated 3 journal manuscripts from the field experiments, and three manuscripts will still be prepared and submitted from the data collected in experiments actually done: one on biopesticides, one on cultivars, and one on integrated management in 3 locations. The planned journal is Crop Protection. What opportunities for training and professional development has the project provided? Three undergraduate students and one graduate student from the agricultural mechanization program at Clemson University were trained in association with evaluating post-harvest disease development. Students: Developed post-harvest treatment protocols and associated analysis. Designed and evaluated a scale immersion hydrocooler (continuation from the previous year). Trained one undergraduate student (Emilee Hyder) from the agribusiness program at Clemson University in survey design and distribution. This student also obtained the CITI certification. Trained three masters students (Shane Behler, Samuel Francis and George Strickland) in survey design and distribution. These students also obtained the CITI certification. Trained one undergraduate student in basic plant pathology laboratory techniques plus DNA extraction, PCR DNA amplification, and use of species-specific primers to identify Alternaria spp. How have the results been disseminated to communities of interest? Agricultural & Applied Economics Association annual meeting in Washington D.C (07/2023). Willingness to pay estimation for organic and local kale. Authors: George Strickland, Felipe de Figueiredo Silva, Michael Vassalos and Joan Ureta. Identifying Characteristics of Consumers Who Take Home Restaurant Leftovers. Authors: Samuel J. Francis, Felipe de Figueiredo Silva, Michael Vassalos and Joan Ureta. Who is the recurrent farmers\' market consumer? Authors: Jane Arnold, Felipe de Figueiredo Silva, and Michael Vassalos. Farmers through extension publications: Is the Transition from Conventional to Organic Kale Production Profitable? At the Southern Ag Today on July 7, 2023 (available at https://southernagtoday.org/2023/07/07/is-the-transition-from-conventional-to-organic-kale-production-profitable/) Authors: Samuel Francis , Felipe de Figueiredo Silva1 and Michael Vassalos Keinath, A. P. 2023. Management of Alternaria Black Spot on Conventional and Organic Kale Grown in the Fall, posted 7/31/2023. https:/blogs.clemson.edu/ipm/management-of-alternaria-black-spot-on-conventional-and-organic-kale-grown-in-the-fall/ Farmers through extension presentations: Keinath, A. P. 2023. Tolerance of Kale Cultivars to Alternaria Leaf Spot (Black Spot) and Ineffectiveness of Biopesticides. 35th Southeast Vegetable & Fruit Expo, Raleigh, NC, 11/30/2022. Keinath, A. P. 2023. Organic kale disease trials and management. Iowa Farm Bureau Tour, Coastal REC, Charleston, SC, 3/30/2023. Keinath, A. P. 2023. 2023 Midlands Vegetable Disease Update: Downy Mildew, Black Rot, Black Spot, and Anthracnose. Midlands Spring Vegetable Meeting, Pelion, SC, 03/07/2023. 2023 American Society of Agricultural and Biological Engineers Annual Meeting in Omaha, NE Identifying Locations for Kale Production in South Carolina: a Suitability Analysis. Authors: Brennan Teddy Aaron P. Turner, Felipe Silva. Burkett, C.D., A.P. Turner, F. Silva, B.E. Teddy, L.A. Samenko, A. Keinath. 2022. Evaluation of a Mobile GIS data Collection Application Combined with Differential GPS for High Accuracy Field Scouting Sonoco FRESH Summit. Clemson University, September 19-21. What do you plan to do during the next reporting period to accomplish the goals? Publish the enterprise budget and generate the fact sheets to be delivered on field days and short courses. (Felipe de Figueiredo Silva, Michael Vassalos and master\'s student) Develop short course on transition from conventional to organic using the budget enterprise developed in the previous years to be used on short courses given to ag educators (teachers, extension agents and agricultural education students) (Felipe de Figueiredo Silva, Michael Vassalos, Anthony Keinath and a master\'s student). Present at least one short course to ag educators. (Felipe de Figueiredo Silva, Michael Vassalos, Anthnoy Keinath and a master\'s student). Finalize the profitability analysis (Felipe de Figueiredo Silva and Aaron Turner). Analyze the two-years data on post-harvesting (Felipe de Figueiredo Silva, Aaron Turner and Anthony Keinath). Finalize and submit three more papers on the consumers surveys - willingness to pay for organic kale, restaurant food waste and based on the data from the farmers markets. (Felipe de Figueiredo Silva, Michael Vassalos and masters\' students) Complete the design of the producer survey to be distributed by Qualtrics to 85 kale producers in the southeastern US, distribute and analyze the data. Produce at least one academic publication and extension material from this data. (Felipe de Figueiredo Silva, Michael Vassalos and Jane Arnold) Field experiments in two locations: on farm at WP Rawl in Pelion, SC (Justin Ballew) and at North Carolina State University in Waynesville, NC (Inga Meadows). Write two academic papers on the field experiments (at Coastal REC Clemson University and the other two locations). (Anthony Keinath) Meadows to establish the fall field trial in Waynesville, NC in August-September 2023 and planned to be complete in Nov-Dec 2023. Ballew to establish the fall field trial in Pelion, SC in August-September 2023 and planned to be complete in Nov-Dec 2023. Organize two field days. (Justin Ballew and Anthony Keinath) Upload videos from the field days. Impacts What was accomplished under these goals? 1. Production Research: As described in the objectives, in the Fall 2022 and Spring of 2023, the best practices identified in year 1 experiments were integrated in a factorial 4 x 3 split-plot design with 4 blocks that includes: 2 biopesticides plus 2 controls (nontreated and copper), whole plot 3 cultivars, split plot. The effects of post-harvest sanitation/cooling method on post-harvest disease development were evaluated in both the Fall 2022 and Spring 2023 harvests. Treatments included placing material directly into storage along with pre-cooling using two common sanitizers. A preliminary evaluation of ultrasonic cleaning was also conducted. 2. Economic Research: Three undergraduate students were (1) trained and developed preliminary enterprise budgets for conventional and organic Kale; (2)improved theresearch scale immersion hydrocooler developed in the previous yearto be used in post-harvest experiments in kale; and (3) design, implemented and analyzed a post-harvest treatment (three treatments) analysis using Ms. Excel and SAS. They presented these outcomes and received feedback for an in-person audience in the Agricultural Sciences Department, Clemson University. A master\'s student developed the conventional and organic enterprise budget for kale.It generated an extension type publication (listed in the publication tab). A master\'s student analyzed the survey on consumers focused on food waste and organic produce consumption. As an outcome, the student presented a poster at the Agricultural & Applied Economics Association annual meeting of 2023 (see list of publications or below). A master\'s student analyzed the survey on consumers focused on the consumption of visually imperfect kale. As an outcome, the student along with the co-advisors submitted the paper to a reputable journal. It is currently a \"Revise and Resubmit\". A master\'s student analyzed the survey on consumers focused on the consumer willingness to pay for organic and local kale. As an outcome, the student presented a poster at the Agricultural & Applied Economics Association annual meeting of 2023 (see list of publications or below). An undergraduate student interviewed more than 100 consumers in the 5 largest farmers market visited in the previous summer (302 consumers interviewed in 19 farmers market in the summer of 2022). An undergraduate student discussing the results of the analysis of the surveys at the farmers markets won first place at the undergraduate research competition at the college level at Clemson University. An undergraduate student discussing the results of the analysis of the surveys at the farmers markets finished third at the undergraduate research competition at the Agricultural & Applied Economics Association annual meeting of 2023. A PhD student presented a poster discussing a preliminary analysis of areas suitable for kale production at the 2023 American Society of Agricultural and Biological Engineers Annual International Meeting. 3. Extension outreach A master\'s student interacted extensively with WP Rawl, one of the farmers collaborators of the grant, on data collection to improve the budget developed in the previous year. This student also reached out to other farmers to refine the budget. One Extension blog post was written by Anthony Keinath (see below). Two presentations were given at a regional grower meeting (see below). One presentation was given at a field day to growers and Master Gardeners (see below). Publications Type: Journal Articles Status: Published Year Published: 2023 Citation: Francis, Samuel; Silva, Felipe de F. and Vassalos, Michael, (2023). Is the Transition from Conventional to Organic Kale Production Profitable? At the Southern Ag Today on

July 7, 2023 (available at https://southernagtoday.org/2023/07/07/is-the-transition-from-conventional-to-organic-kale-production-profitable/) Type: Conference Papers and Presentations Status: Other Year Published: 2023 Citation: Burkett, C.D., A.P. Turner, F. Silva, B.E. Teddy, L.A. Samenko, A. Keinath. 2022. Evaluation of a Mobile GIS data Collection Application Combined with Differential GPS for High Accuracy Field Scouting Sonoco FRESH Summit. Clemson University, September 19-21. Type: Conference Papers and Presentations Status: Other Year Published: 2023 Citation: Strickland, George; de Figueiredo Silva, Felipe; Vassalos, Michael and Ureta, Joan; 2023. Willingness to pay estimation for organic and local kale. Agricultural & Applied Economics Association annual meeting in Washington D.C (07/2023) Type: Conference Papers and Presentations Status: Other Year Published: 2023 Citation: Francis, Samuel; de Figueiredo Silva, Felipe; Vassalos, Michael and Ureta, Joan; 2023. Identifying Characteristics of Consumers Who Take Home Restaurant Leftovers. Agricultural & Applied Economics Association annual meeting in Washington D.C (07/2023) Type: Conference Papers and Presentations Status: Other Year Published: 2023 Citation: Arnold, Jane; de Figueiredo Silva, Felipe and Vassalos, Michael; 2023. Who is the recurrent farmers\' market consumer?. Agricultural & Applied Economics Association annual meeting in Washington D.C (07/2023) Type: Conference Papers and Presentations Status: Other Year Published: 2023 Citation: Teddy, Brennan; Turner, Aaron P. and de Figueiredo Silva, Felipe. Identifying Locations for Kale Production in South Carolina: a Suitability Analysis. 2023 American Society of Agricultural and Biological Engineers Annual Meeting in Omaha, NE Type: Conference Papers and Presentations Status: Other Year Published: 2023 Citation: Arnold, Jane; 2023. Who is the recurrent farmers\' market consumer?. 2022-2023 College of Agriculture, Forestry and Life Sciences Undergraduate Research Symposium and Competition, April 5th, 2023. Student was Advised by de Felipe Figueiredo Silva and Michael Vassalos. Type: Websites Status: Published Year Published: 2023 Citation: Keinath, A. P. 2023. Management of Alternaria Black Spot on Conventional and Organic Kale Grown in the Fall, posted 7/31/2023. https:/blogs.clemson.edu/ipm/management-of-alternaria-black-spot-on-conventional-and-organic-kale-grown-in-the-fall/ **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience: Organic and conventional kale growers; Organic and conventional produce growers; Broad public Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Trained three undergraduate students from the agricultural mechanization program at Clemson University in developing enterprise budgets for conventional and organic kale, using ArcGIS Pro to display and analyze agricultural and agricultural-related variables (e.g., weather and soil types), and the design, development and welding of a scale immersion hydrocooler. Trained one undergraduate student from the agribusiness program at Clemson University in survey design and distribution. This student also obtained the CITI certification. How have the results been disseminated to communities of interest? One virtual presentation at the Long Island Ag Forum, \"Management and Economics of Three Common Foliar Diseases on Cucumber and Leafy Greens.\" Jan. 18, 2022. 101 attendees. Two in-person presentations at the Clemson Coastal Research and Education Center Field Day, \"Organic Management of Alternaria Black Spot on Kale.\" 69 attendees, 97% reported an increase in knowledge. Publication at the website \"Growing Produce\" entitled \"Why Disease Control Is More Challenging on Leafy Vegetables\" on July 5, 2022. What do you plan to do during the next reporting period to accomplish the goals?1. Production research: Testing 3 cultivars sprayed with 3 biopesticides. 2. Economic research: Analyze data on the three consumer surveys. Two students were hired and will start working on the data on Fall 2022. The third student will be hired on summer of 2023. Finalize the designing of the producer survey, distribute it and analyze the results. 3. Extension research: Advise students on building a detailed enterprise budget and on building the profitability map. 4. Graduate education: Expose master students in the Applied Economics program, working on the above mentioned products, to field experiments designed and implemented by the Co-Pi Anthony Keinath. Teach them all the steps of a field experiment, from designing the random experiment to implementing the experiment. **Impacts** What was accomplished under these goals? 1. Production Research Completed four field experiments, conventional and organic in fall 2021 and spring 2022, to evaluate susceptibility of 14 kale cultivars to Alternaria leaf spot. Screened 12 biopesticides in the greenhouse and 10 biopesticides in an organic field experiment in spring 2022. Evaluated two temperatures for postharvest storage with leaves from 14 cultivars. Evaluated citric acid as a postharvest treatment for organic kale with 4 cultivars of green curly kale. 2. Economic Research: Three undergraduate students were (1) trained and developed preliminary enterprise budgets for conventional and organic Kale; (2) trained and developed the initial framework for the state-wide zoning areas where organic kale is profitable; and (3) developed a research scale immersion hydrocooler to be used in post-harvest experiments in kale. They presented these outcomes and received feedback for an in-person audience in the Agricultural Sciences Department, Clemson University. Recruited one graduate student to finalize the budget enterprises and perform the profitability analysis of organic kale in the Fall of 2022 and Spring of 2023. One online consumer survey was designed and distributed through Qualtrics reaching 200 kale consumers to estimate the willingness to pay for organic kale. One graduate student was trained: (1)on survey design; and (2) in the statistical methods that will beused to estimate willingness to pay. This student will work on the survey data during the Fall 2022. A consumer survey was designed and distributed in person at more than 15 farmers markets in SC (a couple in GA and NC) during June-July of 2022 to identify consumer preferences for kale at direct marketing outlets. The final sample is300consumers. One undergraduate was recruited, trained on survey design, and distributed the abovesurvey. The same student also collected data about the characteristics of the markets she visited to distributed the above survey. One online consumer survey was designed and pre-tested with the goal to be submitted in September through Qualtrics and to reach 800 consumers that are aware of kale products. in the process of recruiting one graduate student to work on the outcome of this survey in the Fall 2022 and Spring 2023. 3. Extension outreach The development of the enterprise budgets was initiated by 3 undergraduate students. Specifically, they have collected data on information needed to build the detailed budget such as output and input prices, kale yield (organic and no organic), and input use. **Publications**

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Icorp: Increasing Coastal Organic Rice Production in South Carolina Using Salt Tolerant Cultivars

Accession No.	1027131
Project No.	SC-2021-04810
Agency	NIFA SC.\
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2021-51106-35494
Proposal No.	2021-04810
Start Date	01 SEP 2021
Term Date	31 AUG 2025
Grant Amount	$600,000
Grant Year	2021
Investigator(s)	Ward, B. K.; White, SA, .; Rohila, JA, S..; Cutulle, MA, .; Vassalos, MI, .; Karthikeyan, RA, .

NON-TECHNICAL SUMMARY

Saltwater is a threat to sustainable organic rice production in coastal regions. Climate change effects are seen in rising sea level, increasing salinity in tidal rivers, and flooding of cultivable lands with saltwater. This project\'s long-term goal is to increase organic rice production of coastal South Carolina (SC) by bringing salt-intruded lands to cultivation. We will accomplish this goal by completing the following objectives: (1) Evaluating the impact of saltwater and native weed pressure on plant vigor among diverse rice cultivars/germplasm in greenhouse. (2) Validating salt tolerance and performance of select cultivar in organic-plot-trials. (3) Evaluating agronomic performance of salt-tolerant cultivar in salt-affected, organic farms in coastal SC. (4) Developing enterprise budgets for organic rice production. (5) Evaluating soil and water quality improvements under organic rice production. (6) Developing salt-tolerant pre-breeding lines with \'Carolina Gold\' type traits. Salt-tolerant cultivar selections will be trialed on-farm to determine productivity and grain quality. New, salt-tolerant cultivars will be introduced, expanding potential for organic rice production in salt-intruded lands. Economics of organic rice production detailed, enabling growers to make informed decisions. Ultimately, new cultivars will expand acreage under organic rice production, while ensuring the economic stability of producers and enhancing ecosystem services. This project will address Priority Areas (1) effects of organic practices on soil quality and fertility and understanding of weeds, (2) technologies to document the mitigation ability of organic crops, and (3) cultural practices and cultivars to remove NOP-cited substances and evaluate efficacy based on resulting productivity.

OBJECTIVES

The overall goal of this project is to increase organic rice production in coastal SC on salt-impacted lands. We will accomplish this goal by completing the following objectives: Objective 1: Evaluate the impact of saltwater and native weed pressure on plant vigor among diverse rice cultivars/germplasm in greenhouse.HA1: Saltwater will suppress weeds when salt-tolerant rice cultivars are grown under organic conditions. We will determine the effect of saltwater (representative of organic plot and on-farm locations) and rice cultivar on competition between native weeds and rice crops in pots. We surveyed various SC rice fields and determined the most common weed species are goosegrass (Eleusine indica) and hemp sesbania (Sesbania herbacea), which will be used in the experiments. The greenhouse study will be at the Coastal REC and at Clemson University in Year 1.Objective 2: Validate salt tolerance and performance of select cultivar in organic plot trials.HA2: Salt-tolerant cultivar will grow productively using saline irrigation and organic management practices in field plots.We will use the most salt-tolerant cultivar from the greenhouse trials and the susceptible, commercial cultivar, \'Carolina Gold\'. We will determine the cultivar salt tolerance in addition to yield, grain quality, disease rankings, and overall vigor under field conditions. The plots are on the Yonges loamy fine sand, representative soil found in large portions of coastal SC counties. The plots have entered organic transition to become organic certified and have been under organic conditions for the past two years. The plots are chosen due to its proximity to a tidal salt marsh that often inundates the field, especially under high water events. These plots have a history of poor growth of vegetables and cover crops due to saltwater intrusion. This field\'s proximity to tidal saltwater and our freshwater irrigation infrastructure will allow varied salinity level scenario testing. Plot trials will be conducted during Year 2 and repeated in Year 3.Objective 3: Evaluate agronomic performance of salt-tolerant rice cultivar in salt-affected, organic farms in coastal South Carolina.HA3: Salt-tolerant rice varieties will yield well in organic farms affected by saltwater intrusion in coastal SC.We will grow the same salt-tolerant cultivar used in organic plot trials and in a saltwater intruded agroecosystem. If the rice cultivar exhibits better salt tolerance than the weeds present at the field locations, then the weeds will not be as competitive. Salinity will likely enhance rice vigor while reducing weed pressure, diminishing the need to hand-weed the fields. Rice cultivation costs will decrease with the use of marginal quality (high salinity) water and reduced weed management. On-farm trials will be conducted in four locations along the coastal plain in SC where saltwater intrusion is evident with reduced rice yields. These trials will be carried out in Year 3 and 4 at (1) Turnbridge Plantation (Marion R. Chalmers), (2) Ashe Plantation (John H. Smoak), (3) Lavington Plantation (Jimmy Hagood), (4) Toogoodoo Oyster Company (Andrew Speaker), (5) Rosebank Farms (Sidi Limehouse) and (6) Whitehouse Plantation (Donald A. Quattlebaum). All farms are either certified organic, under organic transition, or are eligible to bypass transition and enter straight into certified organic.Objective 4: Quantifying costs and potential revenue of organic rice production by developing enterprise budgets for organic rice production in coastal region.HA4: The cost of organic production in marginal salt-intruded agricultural lands will be similar to the cost of production in non-marginal land.We will develop enterprise budgets and compare the cost of different production practices, including 1) conventional saltwater rice production with current varieties, 2) conventional saltwater rice production with salt-tolerant varieties, 3) organic saltwater rice production with current varieties, and 4) organic saltwater rice production with salt-tolerant varieties. Economic analysis will be carried out in Year 2, 3, and 4.Objective 5: Evaluate soil and water quality improvements under organic rice production.HypothesisA5.1: Organic management may improve soil and water quality and crop productivity. We will collect soil and water samples periodically throughout the growing seasons from the plots (Year 2 & 3) and the growers\' fields (Year 3 & 4) (both before and after rice trials initiated). Samples will be analyzed for pH, salinity, cation exchange capacity (CEC), nitrate, total N, total P, total C, microbial diversity, and common herbicides. Under organic cultivation, the leaching of nutrients should be minimal. We will analyze leachate and soil samples for salinity, pH, and CEC from the greenhouse study in Year 1 to document the basic soil and water chemistry. Objective 6: Develop salt-tolerant pre-breeding lines with \'Carolina Gold\' type agronomic traits. Hypothesis A6: Salt-tolerant traits from a salt-tolerant rice germplasm can be introgressed into \'Carolina Gold\'. We will initiate a breeding approach to cross \'Carolina Gold\' and/or \'Charleston Gold\' rice with a salt-tolerant line (e.g., \'Doble Carolina\' and/or \'M202\') identified during screening experiments at Clemson Costal REC (Table 1). Thereafter, the desired parent cultivar i.e., \'Carolina Gold\' and/or \'Charleston Gold\' will be used as a recurrent parent; back-crossing will be performed to maximize the \'Carolina Gold\' background traits in the salt-tolerant offspring. From a true hybrid seed, F2:3 population consisting of 250-300 recombinant inbred lines will be generated (Year 1 & 2). We will evaluate those 250-300 F3 \'Carolina Gold\' type rice lines in the greenhouse under tidal saltwater-stress in Year 3 & 4 at Clemson coastal REC. We will advance the individual lines comprised of salt-tolerance and \'Carolina Gold\' grain quality to F7/F8 homozygous state for germplasm release and variety development for salt-intruded coastal regions\' organic rice producers.

APPROACH

Objective 1The Year 1 experiment will be a factorial, completely randomized block design with five replications per treatment with one plant per pot. Experiment treatment factors include: (1) soil type \Yonges loamy fine sand, Kiawah Sandy Loam, and Edisto Muck (thermic Typic Endoaqualfs)\ that represents soils of areas affected by salt intrusion and majority of areas where rice was grown historically; (2) rice cultivar (commercial standard, low-, medium-, and high-salt tolerance); (3) salinity concentration representative of organic plots and growers\' fields \freshwater 0× (control) to 1× (0.375%), 2× (0.75%), and 3× (1.5%)\, and (4) weed competition \rice alone, native weeds alone, native weeds seeded with rice, and native weeds transplanted at the seedling stage with rice\. Native weeds included in the objective will consist of goosegrass (Eleusine indica) and hemp sesbania (Sesbania herbacea). We will conduct preliminary studies to determine the density of weeds that would reduce biomass of \'Carolina Gold\' to use as guidelines for this objective. Plants will be grown in one gallon 25 cm2 surface area pots with water retention pans to achieve complete soil saturation and will be replenished as needed. We will use Nature Safe organic OMRI certified 10-2-8 fertilizer at 150 lb/acre, which is the commercial standard. Objective 2The organic plot trials will be conducted at Coastal REC, Charleston, SC. The experimental design will consist of a completely randomized block design with four replications and a plot size of 4 ft2 with a total of 16 plants each. The treatments will be structured as factorial with four weed-free periods (0, 2, 4, and 6 weeks weed free) by two irrigation regimes (freshwater or salt water from tidal rivers) by two rice cultivars (most salt tolerant selection from the greenhouse screening and the local standard \'Carolina Gold\') for a total of 16 treatments. Seedlings will be planted on 25 cm centers between row and within row. Three-foot-wide beds will act as buffers between beds so that the buffer will be wider to avoid cross treatment contamination. The two center rows will be used for data collection with all the response variables collected and analyzed as in Objective 1. Individual plots will be treated with saline water with a system of dosing pumps. Water for the treatments will come from the brackish water source located on site and diluted to salinity treatment levels described in Objective 1. Organic fertilizer application will follow the prescription as in Objective 1. This plot trial will be repeated twice (Year 2 and 3). Objective 3 The on-farm trials will be conducted at four farms that are either certified organic, under organic transition, or are eligible to be certified organic. All trials will be completely randomized block design and replicated four times with plot size 16\' × 16\' with plants planted 25 cm within row and between rows. In addition, an additional experiment will be performed on all four sites using grower\'s preference rice cultivar spacing that varies from 6\" × 6\" to 9\" × 9\" within and between row spacing, respectively. All response variables mentioned in Objective 1 & 2 will be collected. Data will be analyzed as described in Objectives 1 & 2. These on-farm trials will be repeated twice (Year 3 & 4). Objective 4 Since organic rice is currently a very niche market, it is important to understand its economics and develop plans for growers\' production and investment costs. We will develop and disseminate/provide information to the industry towards the cost of organic rice production in marginal salt-intruded agricultural lands. This objective will be achieved with the use of enterprise budgets. The cost data required for the development of the budget will be obtained from the plot and on-farm trials in Objectives 2 and 3, and from interviews conducted with the farmers who currently produce organic rice. Objective 5 Soil core samples (12 to 15 cm below the surface) from different treatments will be collected in triplicates at regular intervals (starting at pre-treatment as Time 0) for each experiment to track chemical movement and fate in the root-zone of the soil. Soil samples will be homogenized and analyzed for its pH, EC, CEC, ammonium, nitrate, total N, total P, total organic carbon, and microbial diversity (heterotrophic bacteria and fungi) using standard methods. Lysimeters will be installed on plots at 60 cm depth both at Coastal REC and four growers\' farms. Water samples will be collected periodically (starting at pre-treatment as Time 0) throughout the growing season including once after the crop harvest. Leachate collected from pots (greenhouse trials) and pore water from the plots and on-farm trials will be analyzed for pH, EC, CEC, ammonium, nitrate, total N, total P, dissolved organic carbon, trace elements, cations and anions using standard methods. Ten percent of the water samples collected from plot and on-farm trials will be analyzed for select agrochemicals either GC (for volatilized chemicals) or HPLC (for non-volatilized chemicals) pesticides/herbicides panel. Objective 6We will develop \'Carolina Gold\' type rice breeding lines with salt-tolerance and desirable agronomic traits for its successful organic production in coastal regions of SC. To achieve this goal, \'Carolina Gold\' and/or \'Charleston Gold\', highly desirable varieties for organic production in this region, will be crossed with selected salt-tolerant cultivar such as \'Doble Carolina\' and/or \'M202,\' (Year 1 & 2). True-hybrid seeds will be identified by marker-assisted selection and will be back-crossed to \'Carolina Gold\' or \'Charleston Gold\'. After backcrossing, the resulting true-hybrid F1 plant will be selected and selfed for two generations. The F2:3 population, with at least 250-300 recombinant inbred lines, will be developed by the end of Year 2. Salt-tolerance screening of this population (F3 generation) will be conducted in Year 3 using a completely randomized design and three replications at the Coastal REC as explained in the Objective 1. During salt-tolerance screening, data will be collected on agronomic traits such as: chlorosis, transplant injury, tillers number, plant height, heading date, chlorophyll content (using SPAD meter), spikelet sterility, chalkiness, seed length (L), seed width (W), L/W ratio. After evaluating the data, the top 10% of the lines (25-30 lines) with desirable salt-tolerance level, heading date, plant height, spikelet fertility, and grain quality will be selected and further evaluated in greenhouse at the Coastal REC during Year 4 of the project. During the years 3 & 4, the F2:3 generation will be advanced to homozygosity reaching at F7 or F8 generation using greenhouse at the DBNRRC. From the analysis, best breeding lines will be selected for germplasm release and/or variety development by the end of the project. Progress 09/01/23 to 08/31/24 Outputs Target Audience:Target audiences reached by our efforts during this reporting period include all existing and new conventional, transitional, and organic growers, including underrepresented and underserviced minority growers racial and ethnic minorities and those who are socially, economically, or educationally disadvantaged. Also, again in 2023-2024, through the Carolina Gold Rice Foundation (CGRF), a non-profit, audiences were reached out to directly with additions to the board of directors representing these areas of society. In addition, we reached out to the Gullah Geechee Cultural Heritage Corridor, South Carolina. Our audience expands through extension with field days and training. We held three CGRF meetings that were grower and extension trainings and data dissemination points with guest speakers from industry. Additionally, we disseminated data at numerous scientific conferences and at the 2024 International Temperate Rice Conference in New Orleans, Louisana. Our audience included breeders, agronomists, extension and industry stakeholders. Although our breeding work was originally meant as a proactive measure to assist growers prior to the salt intrusion problems becoming worse, more and more growers are taking note of our salt tolerant breeding work as the impacts from rising salt concerns have arrived sooner than anticipated and our growers are in desperate need of germplasm to cope with the rising salt concerns. Changes/Problems:Tropical weather and associated variable tides with variable salt concentrations and the heavy rains made it difficult to maintain the salt concentrations in the experimental fields. What opportunities for training and professional development has the project provided? Nothing Reported How have the results been disseminated to communities of interest?To date, eleven talks and to posters have been given at either scientific conferences or grower meetings. Two manuscripts are currently being developed. Additionally, the concern and rise of interest in coping with salt in local irrigation waters has stimulated interests across commodities and vegetable growers in the field and in CEA agriculture. What do you plan to do during the next reporting period to accomplish the goals?We are on track with regard to our objectives plan and timeline. We plan to continue to reach and meet our objective goals within the timeline of the study. We plan to push 4 lines of salt tolerant (with varying salt tolerances and attributes)rice with the Carolina Gold culinary, historical and cultural values and importance for research on growers\' farms in the spring of 2026. Full scale commercialization of salt tolerant seed will be ongoing. Impacts What was accomplished under these goals? We have completed 4 out of 4 greenhouse trials for Objective 1., on salinity tolerance and weed tolerance. Addressing Objective 6., a stable cross has been made with Carolina Gold and M202 and will enter the spring field trials of Objective 2. Objective 4., has been conducted and data is being analyzed. Currently, we are conducting year 2 of field experiments to compare and validate the salinity tolerance (0, 1.5%, 3%, 6%, and 12% seawater level) six rice genotypes (Carolina Gold, Santee Gold, Doble Carolina, M202, Jupiter and JN100) in the weed free and weed competition scenarios (Fig. 1). Three-week-old rice seedlings were transplanted at a spacing of 25 x 25 cm and a rate of one seedling per hill, after which they were flooded with fresh water. Weed-free plots receive hand weeding twice a week. At the late tillering stage, plants in the control plots are irrigated with fresh water, while plants receiving salinity treatment are supplied periodically (2-3 times per week) with 4 different concentrations of brackish water drawn from a nearby marsh associated with the Stono River. Using a gasoline pump, we collect brackish water from the marsh in a 4000-gallon-capacity reservoir/pool. Based on Atlantic Ocean sampling, we consider 55 dS/m to be the concentration of pure seawater. The calculated volumes are then pumped into the field plots based on each plot\'s fresh and seawater volumes. Every time before application, we use a conversion factor to normalize seawater concentrations based on brackish water\'s electrical conductivity (EC). The salinity level of treated plots is monitored by measuring the EC values. We installed flow meters in each plot to measure the volume applied to each plot. We also measure pH, TDS, Temperature, precipitation and ORP daily. All other response variables mentioned in study 1&2 will be collected. We showcased our research plot at Field Day Talk on June 5, 2024, at Clemson Coastal Research and Education Center, Charleston, SC. The results of this study were presented at ASA, CSSA, SSSA International Annual Meeting in Nov 2023. We are currently repeating this study to validate last years\' results. Currently we have screened our F2 breeding population of approximately 4,000 individual breeding lines, exposed to 30% ocean water, allowed to grow back in freshwater. A rubric of selection criteria was used to move approximately 300 lines forward to the next breeding phase. Ultimately, our long-term goal for this project is to use the cultivars that prove superior through these trials, giving growers the immediate ability to grow where they are not able to now. Eventually, we will use these cultivars in a conventional breeding program to incorporate these salt \1\ tolerant genes into historically significant cultivars like Carolina Gold, Charleston Gold and Santee Gold. Publications Type: Conference Papers and Presentations Status: Other Year Published: 2024 Citation: Singh G., Rohila J., Subudhi P, Vassalos M., Marshall M.W., Karthikeyan R., White S.A., Cutulle M.A. and Ward B. Exploring Salt-Tolerant Germplasm: Alleviating Saltwater Intrusion and Weed Management Issues in Rice in South Carolina in Partial Saltwater Agroecosystem. 2024 International Temperate Rice Conference. (June 6-9, 2024, at New Orleans, LA). Type: Conference Papers and Presentations Status: Other Year Published: 2024 Citation: Singh, G., Cutulle, M. & Ward. B. (2024). Rice Field Trials and Breeding Program Updates. Field Day Talk on June 5, 2024, at Clemson Coastal Research and Education Center, Charleston, SC. Type: Conference Papers and Presentations Status: Other Year Published: 2023 Citation: Singh, G, Ward, B., Karthikeyan, R., Rohila, J., Vassalos, M., Cutulle, M. (2023). Field Evaluation of Salinity Tolerance and Weed Competitiveness of Lowland Rice Genotypes in Organic Production. Meeting Abstract. 2023 ASA-CSSA-SSSA Annual Meeting. St. Louis, Missouri. October 29 - November 1, 2023. Type: Conference Papers and Presentations Status: Other Year Published: 2023 Citation: Singh, G., Karthikeyan, R., Ward, B., White, S., Rohila, J., Vassalos, M., & Cutulle, M. (2023). Salt-Tolerant Rice: Time to Deliver. 2023 CAFLS Graduate Research Symposium, Baruch Institute of Coastal Ecology & Forest Science Georgetown, SC. October 16-17, 2023. Progress 09/01/22 to 08/31/23 Outputs Target Audience:Target audiences reached by our efforts during this reporting period include all existing and newconventional, transitional, and organic growers, including underrepresented and underserviced minority growers racial and ethnic minorities and those who are socially, economically, or educationally disadvantaged. Also, through the Carolina Gold Rice Foundation (CGRF), a non-profit, audiences were reached out to directly with additions to the board of directors representing these areas of society. In addition, we reached to the Gullah Geechee Cultural Heritage Cooridor,South Carolina Department of Natural Resources, South Carolina Department of Agriculture, Clemson University Plant Industry and Clemson

University Crop Improvement Association. Our audience expands through extension with field days and training. We held three CGRF meetings that were grower and extension trainings and data dissemination points with guest speakers from industry. Changes/Problems:We ran into a seeding issue on the first grow out, causing a delay, yet we were able to learn from the mistake, replicated the trial and are now current and on time with our objective goals and timeline. What opportunities for training and professional development has the project provided?Two students, one masters and one doctoral presented their work at multiple venues, including a water quality symposium, and two conferences. How have the results been disseminated to communities of interest?Results have been disseminated to the communities of interest, through Symposia, conference proceedings, and CGRF meetings. What do you plan to do during the next reporting period to accomplish the goals?We are on track with regard to our objectives plan. We plan to continue to reach and meet our objective goals within the timeline of the study. Impacts What was accomplished under these goals? We have completed 3 out of 4 greenhouse trials for Objective 1.,on salinty tolerance and weed tolerance. Addressing Objective 6., astable cross has been made with Carolina Gold and M202 and will enter the spring field trials of Objective 2. Objective 4., is currently being worked on and surveys are scheduled to be sent out to growers this Winter. Currently, we are conducting field experiment to compare the salinity tolerance (0, 1.5%, 3%, 6%, and 12% seawater level) of six rice genotypes (Carolina Gold, Santee Gold, Doble Carolina, M202, Jupiter and JN100) in the weed free and weed competition scenarios (Fig. 1). Three-week-old rice seedlings were transplanted at a spacing of 25 x 25 cm and a rate of one seedling per hill, after which they were flooded with fresh water. Weed-free plots receive hand weeding twice a week. At the late tillering stage, plants in the control plots are irrigated with fresh water, while plants receiving salinity treatment are supplied periodically (2-3 times per week) with 4 different concentrations of brackish water drawn from a nearby marsh associated with the Stono River. Using a gasoline pump, we collect brackish water from the marsh in a 4000-gallon-capacity reservoir/pool. Based on Atlantic Ocean sampling, we consider 55 dS/m to be the concentration of pure seawater. The calculated volumes are then pumped into the field plots based on each plot\'s fresh and seawater volumes. Every time before application, we use a conversion factor to normalize seawater concentrations based on brackish water\'s electrical conductivity (EC). The salinity level of treated plots is monitored by measuring the EC values. We installed flow meters in each plot to measure the volume applied to each plot. We also measure pH, TDS, Temperature, precipitation and ORP daily. All other response variables mentioned in study 1&2 will be collected. We showcased our research plot at Field Day Talk on June 7, 2023 at Clemson Coastal Research and Education Center, Charleston, SC. The results of this study will be presented at ASA, CSSA, SSSA International Annual Meeting in Nov 2023. We will repeat this study next year. Ultimately, our long-term goal for this project is to use the cultivars that prove superior through these trials, giving growers the immediate ability to grow where they are not able to now. Eventually, we will use these cultivars in a conventional breeding program to incorporate these salt-tolerant genes into historically significant cultivars like Carolina Gold, Charleston Gold and Santee Gold. Publications Type: Other Status: Published Year Published: 2023 Citation: 1. Singh, G., Cutulle, M. & Ward. B. (2023). Field evaluation of salinity tolerance and weed competitiveness of lowland rice genotypes in organic production. Field Day Talk on June 7, 2023 at Clemson Coastal Research and Education Center, Charleston, SC. **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience: During our first year, our audiences that were targeted were extension agents, professors within Clemson University and other academic institutions with rice production programs and students who had never had the opportunity to work with rice in South Carolina. We also targeted stakeholders, including landowners and growers directly impacted by salt intrusion. In addition, other state and federal agencies within South Carolina were interested as an audience in how our efforts will benefit the state from a natural resource and ecosystem service perspective. During two of our Carolina Gold Rice Foundation meetings in the Fall of 2021 and Spring of 2022, we had guest speakers and an audience made up of food historians, culinary educators and chefs. There has also been a huge interest in the underserved and underrepresented members of our community in the Gulla Gee Chee Corridor and how through this research and the efforts of Clemson and the USDA are helping to bring rice back to the historic southeast. Changes/Problems: Only one major problem was experienced regarding germination at initiation of the study. We had poor germ due to operator error with regard to germination under an anerobic condition. We quickly solved the problem by pipping seed into transplant or starting seed in pots under restricted water during this phase as occurs in real-world situations. What opportunities for training and professional development has the project provided? Through cooperation with the Carolina Gold Rice Foundation, a grower field day and an annual Fall meeting is planned for October 21st at Clemson's main campus with guest speakers from USA Rice. This event is specific for training purposes as it will cover germplasm, agronomy, horticulture, pathology harvest and postharvest considerations. How have the results been disseminated to communities of interest? Through the 2 student symposiums, three presentations have been given to academia and extension. What do you plan to do during the next reporting period to accomplish the goals?We are currently on track to accomplish our goals moving into year 2 and plan to follow our plan as written in the original proposal. **Impacts** What was accomplished under these goals? We made the two crosses as planned: (i) Carolina Gold x M202, and (ii) Carolina Gold x Doble Carolina. We got F1 seeds and after verifying that they are hybrids (not self) by molecular analysis we will advance to the next step i.e., advancing to F2 generation. Greenhouse experiments with 3 soil types, four cultivars and 4 salinity types are nearing completion. We see definite cultivar x salinity responses, with some cultivars exhibiting better salt tolerance than others both with vegetation and flowering. At the Clemson Coastal Research and Education Center in Charleston, SC, we conducted four greenhouse screenings with Edisto Muck (predominate soil type in the SC Coastal Plain), two focused on the interaction of weeds with rice with 5 salinty levels and four rice genotypes. Two additional studies were performed looking specifically at weed pressure and salinity effects with and Phenospex plant phenotyping hardware and software. Additional field locations on stakeholder lands have been identified as needing salt tolerant germplasm. The economics and surveying team have enrolled a student and the design phase of the economic analysis and survey construction is underway. Field work for on-station trials have begun by leveling a salt inundated field at CREC. **Publications** - Type: Conference Papers and Presentations Status: Accepted Year Published: 2022 Citation: Singh, G., M. A. Cutule, S. White, B. Ward, M. Vassalos, J. S. Rohila, and R. Karthikeyan 2022b. Rediscovering gold: Carolina Gold rice in South Carolina. CAFLS Graduate Research Symposium, Clemson University, Pee Dee REC, Florance, SC, United States - Type: Conference Papers and Presentations Status: Accepted Year Published: 2022 Citation: Singh, G., M. A. Cutulle, S. White, B. Ward, M. Vassalos, J. S. Rohila, and R. Karthikeyan. 2022a. Exploring Salt-tolerant Germplasm to Increase Organic Rice Production in South Carolina. Clemson University Water Research Symposium, Madren Center, Clemson University, Clemson, SC, United States - Type: Conference Papers and Presentations Status: Accepted Year Published: 2022 Citation: Hart, A., Kerrigan, J. and Karthikeyan R. 2022. Sustainability through symbiosis: utilizing fungal endophytes to mitigate salinity stress in Carolina Gold Rice. CAFLS Graduate Research Symposium, Clemson University, Pee Dee REC, Florance, SC, United States

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Evaluating Disease Prevention Methods for Organic American Ginseng Production in Appalachia, an Integrated Research, Education, and Extension Approach

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

NON-TECHNICAL SUMMARY

American Ginseng (AG, Panax quinquefolius L.) is one of the highest unit value cash crops and one of the most well-known medicinal plants originating from North America. After being harvested for over 300 years from the Appalachian Mountains in North America, wild AG has become scarce and now almost all the AGs sold worldwide is cultivated (Liu et al., 2021). Despite its production only contributing to less than 8% of the total world AG production, the demand for high-quality AG has increased steadily in the past decade both domestically and internationally, especially those produced from wild-simulated and/or organically managed systems. Because ginseng is well recognized for its health-promoting properties such as boosting immunity and preventing respiratory diseases (Yuan et al., 2010; Predy et al., 2005), the demand has increased during the COVID-19 pandemic. Particularly, due to the scarcity of dedicated certified organic land in the major ginseng production countries (USA, Canada, China, and South Korea), American farmers have a unique organic market niche available that can greatly enhance sustainability of rural areas that are not suitable for large-scale agronomic crop production but perfectly suited for ginseng growth (e.g. wooded, slopping, and rocky areas). However, the greatest immediate problem challenging organic American ginseng production is fungal diseases control, which typically requires frequent, sometime even daily use of costly fungicides (Davis, 2002). Persistent fungal pathogen issues can not only jeopardize biomass production but decrease microbial diversity in soils, creating a \"replanting issue\" against continuous monoculture production (Li et al., 2020; Yang et al., 2015). Presently, organic and transitional farmers cannot find scientifically published data or Extension publications on how to organically manage fungal pathogen issues in ginseng production. Thus, our goals for this proposed project are to (1) evaluate the effectiveness of biological control microbial agents and botanical extracts on fungal disease prevention and treatment for organic AG production; (2) stabilize changes to the soil microbiome that occur under continuous AG production by increasing native bacterial species known to be antagonist to fungal pathogens and toxin accumulation; and (3) promote sustainable organic production and certification to local, regional and national ginseng producers by emphasizing both the consumer\'s market preference and higher profit margin; (4) develop a comprehensive educational and outreach program to efficiently translate our project findings to stakeholders and the general public. The research components of this multipronged project will increase

agroecosystem resilience while attenuating fungal pathogen pressure and lessening the replanting digression issue. Additionally, we will rely on established education and Extension network to disseminate our findings to different stakeholder groups on a regional and national scale. The proposed program would be the first multi-institutional, multidisciplinary, and collaborative project on organic AG production across the Appalachia region; which could cohesively bolster organic AG production, increase market competitiveness and diversity for organic ginseng producers, enhance the economic sustainability in rural areas that mainly supports ginseng production, and maintain values and ethnic traditions in American rural communities as a whole.

OBJECTIVES

The four pillars in the sustainable agricultural system are commonly considered as production efficiency, economic dynamics, ecological impacts, and social responsibility. Our ultimate goal of this project is to develop scientific solutions for and to promote sustainable organic AG production in Appalachia using an integrated research, education, and extension approach (Fig. 1). A four-stage research effort will be conducted sequentially in laboratory, the green house, small-plot organic lands; and producer sites. All four research stages will be integrated with education and extension components. This multipronged system approach will help addressing key managerial issues challenging organic AG production and help increase biodiversity both above and below ground resulting in a more resilient ecosystem while attenuating fungal pathogen pressure and lessening the replant issue. This approach may be easily adapted by regionally divergent farms by adjusting selected bacterial endophyte and cover crop species. Specifically, we have five objectives of this program. Objective 1: Evaluate the effectiveness of biological control microbial antagonists on fungal disease prevention and treatment for organic AG production. The use of biological control agents to both suppress pathogen presence and promote growth in organic agriculture is well documented (O\'Callaghan, 2016). However, few studies have demonstrated their effectiveness on ginseng production. Many of these studies were carried out using P. ginseng. Some bacterial antagonists are already on the market for control of Pythium; Companion (B. subtilis), Primastop (Gliocladium caterulatum), Actinovate (Streptomyces lydicus), Mycostop (Streptomyces griseovirdis), PlantShield (Trichoderma harzanum), and SoilGard (Trichoderma virens) are all marketed for use against Botrytis, Fusarium, Phytophthora, and Rhizoctonia (Moorman, 2011). These products however, do not specifically mention their use or efficacy on AG (P. quinquefolius). Here we seek to fill in gaps in our collective knowledge of how the use of biological agents will protect AG production. Fungal pathogens tend have a limited range of host species that they harm, often refereed to has host specificity (Li, Cornelissen, & Rep, 2020). Because of this circumstance, the fungal pathogens effecting AG will be collected and identified from wild environments, collaborating ginseng growers and academic researchers. Meanwhile, bacterial endophytes from regional AG genotypes will also be collected, screened against the isolated pathogens, and identified. The effect of the bacterial antagonists on the growth of AG plant and plant resistance to fungal disease will be investigated. In addition, because phytochemical content is one of the key factors determine ginseng\'s value and it has been reported that bacterial antagonist could increase the phytochemical contents, the phytochemical accumulation after bacterial inoculation will also be investigated. Objective 2: Evaluate the effect of biological control microbial antagonists on soil physiochemical and biological conditions. Soil-borne ginseng fungal pathogens alter the soil microbiome by reducing the species and growth of beneficial bacteria. Our hypothesis is that by introducing or increasing native bacterial species known to be antagonist to fungal pathogens, we can restore the bacterial diversity and population size of antagonistic bacteria that were altered by the fungal pathogen or continuous ginseng production. Our approach will be to assess bacterial diversity and population size in the rhizospheric soil of healthy and diseased AG. Metabarcode analysis will be used to survey prokaryotic and fungal taxa associated with healthy and diseased AG plants. If specific taxa are found to be associated with healthy AG plants it may be possible to identify those taxa and introduce them into the soils as part of an organic cultivation strategy. These results will allow us to quantify bacterial population and diversity reductions in soil involved in AG production and offer an important baseline number. Bacterial strains shown to be antimicrobial will then be reintroduced into ginseng production fields at levels at or above our baseline finding. Objective 3: Evaluation of the antifungal effect of natural botanical extracts against AG\'s fungal pathogens. The severity of ginseng replant disease appears linked to the production environment. While replant failure is common in cultivated AG production, it is much less common in forest farmed AG cropping systems. However, fungal disease tends to increase with increasing intensification of forest farming practices. Wild populations of AG contain assemblages of associated plant species, and growers evaluating sites for wild-simulated plantings use these associated plants as \'indicator species\' in determining suitability for AG reintroduction. Some of these indicator plant species (i.e. Adiantum pedatum, Arisaema triphyllum, Botrychium virginianum, Caulophyllum thalictroides, and Podophyllum peltatum, Polygonatum biflorum), as well as some woodland companion crops sometimes interplanted with AG (i.e. Allium tricoccum, Cimicifuga racemosa, Hydrastis canadensis), are reported to possess anti-fungal properties. We hypothesize that these plant associates contribute to the reduced disease incidence found in wild or wild-simulated AG populations through antifungal root exudates or compounds in decomposing leaf litter. To test this hypothesis, we will evaluate the antifungal potential of ethanol and aqueous extracts made from select indicator species and companion crops with the goal of developing simple DIY anti-fungal soil treatments that will be shared with growers through our outreach efforts. We will identify these select candidates for study using grower experience coupled with our knowledge of associated flora and possible novel antifungal chemistry associated with a particular species. Objective 4: Promote sustainable organic production and certification to local, regional and national ginseng producers by emphasizing both the consumer\'s market preference and higher price yield the anticipated research solutions will deliver. The authentication of herbal products through organic certification provides confidence and quality assurances to consumers who are willing to pay for the price premium of certified ginseng products that involve no chemical inputs. Two current examples are the \'Grown in Wisconsin\' Seal - simple geographic certification that has increased demand and relative market price (Ginseng Board of Wisconsin 2021); and in Asia, the Chinese \"Green Food Certificate\" (a partial equivalent to our USDA organic certification) also drives both demand and price for organic products (Liu et al., 2021; China Green Food Development Center). We will develop a market analysis for the cost/return of AG organic transitioning and production and design training models that will help AG producers to become certified. Our outreach will include a training component for ginseng producers by promoting sustainable organic management techniques and certification and on how to niche-market their product at higher prices.Objective 5: Disseminate and transfer the project results to stakeholders and public individuals.Results and best practices identified through this work will be made available through various educational and outreach efforts conducted by project team members and collaborators in various Appalachian states (TN, PA, OH, VA, NC, KY, and NY). An educational component includes teaching activities at MTSU, University of Tennessee, UVA-Wise, and Penn State University and undergraduate research activities in these institutions will be developed.

APPROACH

3.1 Methods for Objective 1.Solicit stakeholder involvement to identify and collect plant materials, bacterial endophytes, and pathogenic fungi The IGI at MTSU will collect both healthy and diseased samples from growers, researchers, and community donors actively solicited by the Tennessee Department of Environment and Conservation (TDEC), the Soil, Plant, and Pest Lab at the University of Tennessee Extension Service, and the North Carolina State University Extension.Collection and Identification of pathogens affecting AG Pathogenic fungi will be isolated or obtained from: 1) symptomatic plants produced from fields and forests of our regional farmer cooperators, and 2) academic plant pathology research laboratories. Infected samples will be triaged in the plant pest diagnostic laboratory at the University of Tennessee Soil, Plant and Pest Center in Nashville, TN.Collection and Identification of bacterial biological control agents (BCAs) and plant growth promoting rhizobacteria (PGPR) from regional AG populations Bacterial BCAs and plant growth promoting rhizobacteria will be isolated from roots of regionally produced AG from our farmer cooperators fields and forests.In vitro & in vivo evaluation of antifungal activity of bacterial BCAs Upon successful isolation, these bacterial endophytes will be screened for their ability to: 1) suppress fungal pathogen growth in vitro by direct (physical contact) inhibition via dual culture assay.2) Suppress fungal pathogen infection in vivo by inoculating AG plants with suspected bacterial antagonist (identified previously) and planting these into soil infested with a pathogen.3) Promote AG growth rate in vivo by inoculating seedlings with liquid cultures of the bacteria and recording growth rate, plant bio-mass, and chlorophyll content using AG seedlings grown in a controlled growth chamber environment. 4) Bacterial endophytes shown to possess efficacy against fungal infection from the growth chamber experiments will advance for further evaluation under greenhouse conditions.Field test of antifungal activity of bacterial BCAs The field trial site is located at the MTSU Experiential Learning and Research Center.Bacterial endophytes shown to possess good efficacy for disease control and/or growth promotion will advance to field trials. These isolates will be cultured in appropriate liquid media and applied to AG by basal drench to established AG plants actively growing in the organic field. Alternatively, when establishing new field sites, AG seedling roots will be dipped liquid suspension of bacterial endophyte and transplanted in the organic field under the artificial shade.3.2 Methods for Objective 2.Soil sample collection Soil samples will be collected from April through October during ginseng\'s growing season.Assess the changes of soil physicochemical properties and nutrients with the presence of fungal pathogens Soil samples associated with healthy and symptomatic AG plants will be analyzed and compared for soil physiochemical properties and nutrients.Assess the changes of soil biological condition with the presence of fungal pathogens Bacteria and fungi in soil samples associated with healthy and symptomatic AG plants will be surveyed with metagenomic barcoding and compared. For bacterial metabarcoding, the V4 region of the 16S rRNA gene is used to estimate microbial biomass and identify microbial species.Evaluate the potential of bacterial BCAs on restoring the soil microbiota altered by fungal pathogens.3.3 Methods for Objective 3.Solicit stakeholder involvement to identify and collect plant material and pathogenic fungi A meta-analysis will be conducted in conjunction with solicitations of AG growers within our network for historical disease incidence within their AG plots containing differing quantities and densities of indicator species or interplanted companion crops. Identify and collect plant materials Plant material from indicator and companion crop species that have been shown to exhibit antimicrobial activity will be collected from actively growing wild or wild-simulated ginseng populations in our farmer cooperators fields and forests. The aqueous and ethanolic extracts of plant materials from indicator and companion crop species will be prepared using a sonication extraction method (Vinatoru, 2001).In vitro & in vivo evaluation of antifungal activity of plant extracts Plant extracts will be assessed for their antifungal activities in vitro and in vivo.In vivo evaluation will be conducted in the MTSU greenhouses using methods described in the in vivo fungal suppression portion of Objective 1, but substituting plant extracts for the bacterial cultures.Phytochemical analysis of effective plant extracts Plant extracts that are shown to possess efficacy against fungal infection from the in vitro and in vivo experiments will be subjected to phytochemical analysis using ultra high performance liquid chromatography (UHPLC) to determine the main active phytochemicals responsible of the antifungal activity.Field test of botanical extract pathogen suppression Field tests will be conducted in the certified organic land the MTSU Experiential Learning and Research Center in Lascassas, TN. Plant extracts that exhibited antifungal activity in the lab and greenhouse studies will be used as a seed treatment prior to field planting.3.4 Methods for Objective 4.A market analysis for the cost/return of organic transitioning and production This analysis will include budgeting methodology and key component sensitivity tools for the producer to estimate the annual cost of organic production once the transition phase is complete. Taken together with market price data for the organic product, this information will provide a break even estimate for the organic producer.Training events in Tennessee The IGI at MTSU and UT Extension will host training events.Training events in Pennsylvania Team member Dr. Burkhart will organize and lead the development of extension and outreach events through the Shaver\'s Creek Environmental Center and Forest Resources Extensionat PSU.Training events in Ohio Projector collaborator Dr. Leopold will lead the outreach using existing events hosted by United Plant Savers (UpS), Ohio.Training events in North Carolina Projector collaborator Dr. Hamilton manages a robust program of ginseng and forest-farming outreach in North Carolina offering production workshops and other demonstrations including field days. He will lead the outreach using this existing program at NC Cooperative Extension.3.5 Methods for Objective 5.Dissemination methods Results and best practices identified through this work will be made available through the following dissemination methods by project team members and collaborators: 1) Print media including journal articles, extension publications, brochures, etc.; 2) Existing electronic media including the International Ginseng Institute (IGI)\'s website and TDEC\'s ginseng website, newsletters, and Departmental Twitter and Facebook accounts; 3) Presentations at local, regional, and national academic conferences; and 5) Grower meetings, demonstrations, field visits, and workshops that will be held on multiple sites.Teaching activities at MTSU, UT, UVA-Wise, and PSU Thirteen undergraduate courses taught at MTSU, UVA-Wise, and PSU could greatly benefit from this project.Undergraduate student research activities at MTSU and UVA-Wise The project team members at both institutions will recruit more than ten undergraduate researchers during the project period. These students will be encouraged to disseminate their research associated with organic agriculture production by joint scientific publication and conference presentation. Progress 09/01/23 to 08/31/24 Outputs Target Audience:Our target audience included undergraduate and graduate students at the five participating and collaborating institutions, as well as ginseng growers, producers, dealers, and researchers across Tennessee, Virginia, and Pennsylvania. Additionally, our outreach events drew public attendees and engaged diverse groups, including local herbal business owners, state park representatives, and state foresters. Changes/Problems:We requested and received approval for a one-year no-cost extension (NCE), extending the termination date to 8/31/2025. Additionally, we submitted a budget revision to address changes in personnel (a co-PI moved to another institution, the evaluator passed away, and a technician was replaced with a postdoctoral research fellow) as well as adjustments to subawards. Both the extension and budget revision have both been approved. What opportunities for training and professional development has the project provided?The project continues to impact students\' professional development through six renovated courses that influenced over 100 students at the principal investigator\'s institution. Additionally, during the third reporting period, the project provided experimental and professional training to nine students, enhancing their academic development. Internship opportunities created within the project facilitated institutional exchange and furthered student career development. As an extension of the current grant, the project team submitted a proposal to the USDA Organic Transition Grant in 2023 (not funded) and another to the USDA NRCS Conservation Innovation Grant in 2023 (funded). How have the results been disseminated to communities of interest?Results and best practices identified through this work were disseminated through various educational and outreach efforts as shown in Accomplishments of Objective 5. What do you plan to do during the next reporting period to accomplish the goals?We plan to continue our research agenda into the next reporting period as we work toward concluding the project. At the same time, our outreach efforts to promote sustainable organic production and certification among ginseng producers will remain active, along with ongoing dissemination of results to stakeholders. Impacts What was accomplished under these goals? Objective 1: Evaluate the effectiveness of biological control microbial antagonists on fungal disease prevention and treatment for organic American Ginseng (AG) production. Accomplishments:We have designated a 10-by-50 ft plot in the experiential learning laboratory at the university farm for our study. Raised beds and a shade structure have been constructed, and the plot is certified organic. However, due to extreme drought in the summer of 2024, we were unable to conduct the field study. With the grant extended by one year, we plan to resume the study in the summer of 2025. Objective 2: Evaluate the effect of biological control microbial antagonists on soil physiochemical and biological conditions. Accomplishments:We are continuing the study comparing the bacterial soil microbiome of healthy and diseased American Ginseng for the potential development of organic fungicides. Our manuscript \"The Soil Microbiomes of American Ginseng (Panax quinquefolius) Cultivated in North America Differ by Location But Not Always by Disease Status\" was published on PhytoFrontiers in 2024. Objective 3: Evaluation of the antifungal effect of natural botanical extracts against AG\'s fungal pathogens. Accomplishments:We are continuing our study on antifungal botanical extracts identified during the previous reporting period. This includes examining the phytochemical profile and antifungal properties of goldenseal extract, along with several other promising candidates. Our manuscript \"Goldenseal (Hydrastis canadensis L.) extracts inhibit the growth of fungal pathogens in American ginseng (Panax quinquefolius L.)\" was published on Molecules Special Issue: Phytochemicals: Extraction,Bioactivities, and Applications in 2024. Additionally, we presented findings on botanical extracts from goldenseal, ginseng, and sweet wormwood (Artemisia annua L.) at four national, regional, and local conferences and meetings. Objective 4: Promote sustainable organic production and certification to local, regional, and national ginseng producers by emphasizing both the consumer\'s market preference and the higher price yield the anticipated research solutions will deliver. Accomplishments:We have actively promoted sustainable organic management techniques and certification through workshops and presentations at local and regional conferences for ginseng producers. We co-hosted and presented at the Tennessee ginseng diggers and growers workshop in Pikeville, TN in the fall of 2023 to encourage organic certification for ginseng cultivation. Additionally, we participated in the 2024 \"Gather to Grow\" Forest Farming Conference in Roanoke, Virginia, where Dr. Eric Burkhart (Co-PI) hosted a roundtable discussion on ginseng pest management and highlighted organic approaches for managing ginseng diseases. Objective 5: Disseminate and transfer the project results to stakeholders and public individuals. Accomplishments:Results and best practices identified through this work have been shared through various educational and outreach initiatives. In addition to the workshops and conferences mentioned under Objectives 3&4, we presented on American ginseng conservation at the Conservation Days event at the Barfield Crescent Park in May 2024. We continue to offer six renovated undergraduate and graduate courses to over 100 students at MTSU, which incorporate elements of organic cultivation and sustainable agriculture. Furthermore, nine students (one Ph.D. student, one Master student, and seven undergraduate students) at MTSU, UVA, and PSU have actively participated in research related to this project. Of these, four students presented findings at local, regional, and national conferences, showcasing results and contributing to broader discussions of the project. Publications Type: Peer Reviewed Journal Articles Status: Published Year Published: 2024 Citation: Maggard, I. J., Deel, K. B., Gao, Y, Cahoon, A. B. (2024) The Soil Microbiomes of American Ginseng (Panax quinquefolius) Cultivated in North America Differ by Location But Not Always by Disease Status. PhytoFrontiers. Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Alnassari, Z., Alnassari, K., Gao, Y., Zhang, M. (2024). Optimization of a Rapid and Efficient Method for Ginsenoside Extraction. 2024 National Conference on Undergraduate Research (NCUR). Long Beach, CA. April 8-10, 2024. Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Isaiah Kam, Gao, Y. (2024). Extraction of sweet wormwood (Artemisia annua L.), a medicinal plant, and evaluation of its terpene content. MTSU Scholar Week. Murfreesboro, TN. March 15, 2024. Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Moore, R., Zhang, M., Gao, Y. (2024). An Untargeted Metabolomic Approach to Studying Anti-Fungal Treatments American Ginseng (Panax quinquefolius). MTSU Scholar Week. Murfreesboro, TN. March 15, 2024. Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Gao, Y. (2024). Inhibitory Effects of Goldenseal (Hydrastis canadensis L.) Extracts on Fungal Pathogens in American Ginseng (Panax quinquefolius L.) 2024 American Phytopathological Society (APS) Southern Division Meeting. February 26-29, 2024, Columbia, SC. Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Isaiah Kam, Gao, Y. (2024). Extraction of sweet wormwood (Artemisia annua L.), a medicinal plant, and evaluation of its terpene content. 2024 Annual Posters at the Capital. Nashville, TN. February 14, 2024. Type: Peer Reviewed Journal Articles Status: Published Year Published: 2024 Citation: Gao, Y.*, Swiggart, E., Wolkiewicz, K., Liyanapathiranage, P., Baysal-Gurel, F., Avin, F. A., \... & Burkhart, E. P. (2024). Goldenseal (Hydrastis canadensis L.) Extracts Inhibit the Growth of Fungal Isolates Associated with American Ginseng (Panax quinquefolius L.). Molecules, 29(3), 556. Progress 09/01/22 to 08/31/23 Outputs Target Audience:The target audience we reached includes undergraduate and graduate students at the five participating and collaborating institutions, as well as over 200 ginseng growers, producers, dealers, and researchers in Tennessee, Maryland, North Carolina, and Wisconsin. Additionally, our outreach events attracted public attendees who participated in our outreach events, and we engaged with interested groups such as local herbal business owners, state parks, and state foresters. It\'s worth noting that ginseng growers come from traditionally underserved communities of all ethnicities. Changes/Problems:We experienced two changes in personnel during the 2022-2023 project period. Unfortunately, our project external evaluator, Mr. Robert \"Bob\" Beyfuss, passed away in 2023. We have now identified a replacement, Dr. Ying Jin, who will be involved in this project during the 2023-2024 time period.Another change involves the project co-PI, Dr. Seockmo Ku, who transitioned from the project host organization (MTSU) to Texas A&M University in August 2023. Dr. Ku will continue collaborating with the project team on the ongoing research. What opportunities for training and professional development has the project provided?The project significantly impacted students\' professional development through six renovated courses that influenced over 100 students at the principal investigator\'s institution. Additionally, during the second reporting period, the project provided experimental and professional training to 11 students, enhancing their academic development. Internship opportunities created within the project facilitated institutional exchange and furthered student career development. Furthermore, the grant elevated the visibility of the research work leading to invitations to the investigators for seminars, conferences, and academic exchanges. The subsequent section details the major events attended. Beyond these formal gatherings, the increased visibility generated numerous phone calls, emails, and follow-up contacts with individuals who might not have otherwise been aware of the program\'s work. Furthermore, the work covered in this grant has paved the way for our next grant application. The project team submitted a grant proposal to the USDA Federal-State Marketing Improvement Program (FSMIP) and a grant proposal to the USDA NRCS Conservation Innovation Grant in 2023. How have the results been disseminated to communities of interest?Results and best practices identified through this work were disseminated through various educational and outreach efforts as shown in Accomplishments of Objective 5. What do you plan to do during the next reporting period to accomplish the goals?We intend to carry on our research agenda in the next reporting period. Having identified and tested promising antifungal biocontrol agents in vitro, we will further assess their effectiveness in the greenhouse and field. Meanwhile, our outreach efforts to promote sustainable organic production and certification to ginseng producers will persist, along with the ongoing dissemination of the results to stakeholders. Impacts What was accomplished under these goals? Objective 1: Evaluate the effectiveness of biological control microbial antagonists on fungal disease prevention and treatment for organic American Ginseng (AG) production. Accomplishments:We are continuing our work on the isolated and identified ginseng fungal pathogens from the first reporting period. To date, three manuscripts detailing the identification of novel ginseng pathogens have been published in Plant Disease. We also presented the pathogenicity of fungal and bacterial species associated with American ginseng at the Tennessee Academy of Science annual meeting and shared insights into the diversity of the fungal community associated with American ginseng at the 2023 American Phytopathological Society (APS) Annual Meeting - South Division. Additionally, our efforts persist in exploring the antifungal properties of the bacterial endophytes isolated and identified during the first reporting period, utilizing in vitro bioassays. This work is currently in progress. In preparation for the live plant study, we have established two raised beds for planting ginseng stock plants and constructed six plant growth chambers for antifungal assays with live plants. We have acquired approximately 150 three-year-old ginseng plants for use in live assays. Objective 2: Evaluate the effect of biological control microbial antagonists on soil physiochemical and biological conditions. Accomplishments:We are continuing the study comparing the bacterial soil microbiome of healthy and diseased American Ginseng for the potential development of organic fungicides. Soil samples from both healthy and diseased plants in Maryland and Wisconsin were analyzed using environmental DNA metabarcoding to identify predominant bacteria and fungi. Statistical analyses revealed significant differences in alpha- and beta-diversity between locations and inconsistencies in microbial communities associated with diseased plants, advancing our understanding of ginseng soil rhizomes. The findings on the soil microbiomes of healthy vs. blighted cultivated ginseng roots were presented at the 2022 annual meeting of the American Society for Microbiology and the 84th annual meeting of the Association of Southeastern Biologists. Our manuscript on this work was recently accepted by PhytoFrontiers. Objective 3: Evaluation of the antifungal effect of natural botanical extracts against AG\'s fungal pathogens. Accomplishments:We are continuing the study of antifungal botanical extracts selected during the first reporting period. We have examined the phytochemical profile and antifungal properties of goldenseal extract, along with a few other promising botanical extracts. Our manuscript \"Goldenseal (Hydrastis canadensis L.) extracts inhibit the growth of fungal pathogens in American ginseng (Panax quinquefolius L.)\" was recently submitted to the Molecules Special Issue: Phytochemicals: Extraction,Bioactivities, and Applications. Additionally, we presented this work at the Tennessee Academy of Science annual meeting. Objective 4: Promote sustainable organic production and certification to local, regional, and national ginseng producers by emphasizing both the consumer\'s market preference and the higher price yield the anticipated research solutions will deliver. Accomplishments:We conducted an economic study to assess the implications of transitioning from traditional methods of producing ginseng to organic cultivation. The study evaluated the profitability of each method by analyzing costs, expenses, and yields. Our findings suggest that transitioning to organic ginseng reduces the ginseng yield per acre, but the net income for farmers increases substantially. This implies that organic ginseng has significant agribusiness entrepreneurial potential, fostering profitable and sustainable agricultural practices. Our work on the financial implications of transitioning to organic ginseng was presented at the 2023 International Conference of the Institute for Global Business Research (IGBR). Furthermore, we are actively promoting sustainable organic management techniques and certification through workshops, as well as local and regional conferences aimed at ginseng producers. Notably, we hosted a statewide ginseng cultivation workshop in Tennessee with approximately 50 participants and co-hosted a ginseng growers\' workshop, where we provided training and spoke about organic ginseng cultivation and certification. Objective 5: Disseminate and transfer the project results to stakeholders and public individuals. Accomplishments: Results and best practices identified through this work have been made available through various educational and outreach efforts. Workshop, growers meeting, field day, demo day: We organized and hosted the Fall 2022 Ginseng workshop at Barfield Crescent Park, Murfreesboro, TN, in October 2022. Four invited speakers presented ginseng harvest data, regulation, site evaluation, planting techniques, intercropping, and growth management techniques. Around 50 participants learned the proper use of dedicated hand tools and planting techniques through expert demonstrations in the Park\'s natural forest using native seeds. We also distributed 5 pounds of ginseng seeds and goldenseal rootlets to participants for free. Additionally, we participated in and presented American ginseng organic cultivation at the Virtual Field Day at MTSU in March 2023. We co-hosted and presented at Boring Ginseng Roots and Herbs\' annual growers\' meeting and training workshop in August 2023, engaging in discussions with growers, diggers, buyers, and representatives from herbal companies. Public outreach: We participated in and presented American ginseng conservation at the Barfield Crescent Park Conservation Days event in June 2023. The project team transplanted 50 native ginseng rootlets in the hardwood forest at the Biltmore Estate, Ashville, North Carolina, as part of their Naturalist program. The project team has also conducted over ten meetings (both in-person and virtual) and farm visits with ginseng growers, stakeholders, and collaborators. Digital outreach: Ginseng newsletters (Fall 2022 and Spring 2023 issues) were distributed to 200+ participants via email. Educational component: A component supporting teaching activities at MTSU, University of Tennessee, UVA-Wise, and Penn State University, as well as undergraduate research activities at these institutions, was developed. We continue to offer six renovated undergraduate and graduate courses that include organic cultivation and sustainable agriculture elements, to over 100 students at MTSU. A total of 11 students (one Ph.D. student, three Master students, and seven undergraduate students) at MTSU and UVA have participated in the research of this project, with seven of them presenting at local, regional, or national conferences to report results from the project. Publications Type: Journal Articles Status: Accepted Year Published: 2023 Citation: Maggard, I. J., Deel, K. B., Gao, Y, Cahoon, A. B. (2023) The Soil Microbiomes of American Ginseng (Panax quinquefolius) Cultivated in North America Differ by Location But Not Always by Disease Status. Accepted by PhytoFrontiers on Nov 19, 2023. Type: Journal Articles Status: Published Year Published: 2023 Citation: Liu, Z., Moore, R., Gao, Y., Chen, P., Yu, L., Zhang, M. and Sun, J. (2023). Comparison of Phytochemical Profiles of Wild and Cultivated American Ginseng Using Metabolomics by Ultra-High Performance Liquid Chromatography-High-Resolution Mass Spectrometry. Molecules, 28(1), p.9. Type: Journal Articles Status: Published Year Published: 2023 Citation: Liyanapathiranage, P., Avin, F.A., Swiggart, E., Lopez, E.F., Parajuli, M., Oksel, C., Gao, Y. , Baysal-Gurel, F. (2023). First Report of Leaf Spot of Panax quinquefolius Caused by Pestalotiopsis nanjingensis in Tennessee and the United States. Plant Disease. (Co-corresponding authors). Type: Journal Articles Status: Published Year Published: 2023 Citation: Liyanapathiranage, P., Avin, F.A., Oksel, C., Swiggart, E., Gao, Y. , Baysal-Gurel, F. (2023) First Report of Rusty Root of Panax quinquefolius Caused by Pseudomonas marginalis in Tennessee and the United States. Plant Disease. (Co-corresponding authors). Type: Journal Articles Status: Submitted Year Published: 2024 Citation: Goldenseal (Hydrastis canadensis L.) extracts inhibit the growth of fungal pathogens in American ginseng (Panax quinquefolius L.). Submitted to Molecules Special Issue: Phytochemicals: Extraction, Bioactivities and Applications. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Maggard, I. J., Deel, K. B., Gao, Y., Cahoon, A. B. (2022). Soil Microbiomes of Healthy vs Blighted Cultivated Ginseng (Panax quinquefolius) Roots. 2022 annual meeting of the American Society for Microbiology, Kentucky/Tennessee Brach. Johnson City, TN. October 21-22, 2022. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Wolkiewicz, K., Swiggart, E., Gao, Y. (2022). Extraction efficiency of goldenseal (Hydrastis canadensis L.) using different solvents and plant tissues. The 132nd Tennessee Academy of Science annual meeting, Nashville, TN. November 18, 2022. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Liyanapathiranage, P., Avin, F.A., Oksel, C., Swiggart, E., Gao, Y., Baysal-Gurel, F. (2022). Pathogenicity of fungal and bacterial species associated with American ginseng (Panax quinquefolius). The 132nd Tennessee Academy of Science annual meeting, Nashville, TN. November 18, 2022. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Oksel, C., Liyanapathiranage, P., Avin, F.A., Swiggart, E., Gao, Y., Baysal-Gurel, F. (2023). Insights into the diversity of the fungal community associated with American ginseng (PanaxquinquefaliusL.). 2023 American Phytopathological Society Annual Meeting - South Division. Durham, NC. February 13-16, 2023. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Maggard, I. J., Deel, K. B., Gao, Y., Cahoon, A. B. (2023). Soil Microbiomes of Healthy vs Blighted Cultivated Ginseng (Panax quinquefolius) Roots. The 84th annual meeting of the Association of Southeastern Biologists. Winston-Salem, NC. March 23-26, 2023. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Conference Oral Presentation: Bernard, E.C., Lopez, E.F., Gao, Y., Swiggart, E. (2022). Leaf lesions on American Ginseng associated with a foliar nematode, Aphelenchoide ssp., in

Tennessee. The 61st Annual Meeting of the Society of Nematologists. Anchorage, Alaska, September 26-29, 2022. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Conference Oral Presentation: Moore, R., Liu, Z., Sun, J., Gao, Y., Zhang, M. (2022). Metabolomic Study of Wild American Ginseng and Cultivated American Ginseng Roots by UHPLC-HRMS and Chemometrics. 2022 SCIX Conference, October 2-7, 2022. Type: Other Status: Published Year Published: 2023 Citation: 2023 Spring Ginseng Newsletter Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Gao Y. (2023) Evaluating disease prevention methods for organic American ginseng (Panax quinquefolius) production in Appalachia. USDA NIFA: OREI & ORG Project Directors Meeting. Washington D.C. Apr 19-20, 2023. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Arik, M., Gao, Y., Ho, H. (2023). Financial Implications of Transitioning to Organic Ginseng for Agribusiness. Institute for Global Business Research (IGBR) International Conference. Nashville, TN. April 19-21, 2023. **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience:The target audience we reached during the first reporting period includes undergraduate and graduate students at the five participating and collaborating institutions, over 200 ginseng growers, producers, dealers, and researchers in Tennessee, Maryland, North Carolina, and Wisconsin, over two thousand general public attendees who participated in our outreach events (e.g. Conservation Days and Smithsonian's Folklore Festival), and interested groups such as local herbal business owners, state parks, and state foresters. Ginseng growers are traditionally from underserved communities of all ethnicities. No economic demographic data was collected. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?This grant has provided some exceptional and even unexpected opportunities for both training and professional development. It has had an impact beyond the anticipated goals in ways that were not envisioned when the grant was sought. In short, early success brought publicity and the publicity opened new avenues for stakeholders, students, and the principal investigators. As an example, the grant activities were noticed by the Smithsonian Institution where the PD, PIs, and the project's lab assistants were invited to present and disseminate knowledge, techniques, and results to approximately 500,000 visitors over seven days at the Smithsonian's Folklife Festival held on the National Mall in Washington DC. Numerous professional contacts were made that have resulted in a broader mind share of the issues involved. An entirely new stakeholder constituency was created by this exposure and individual student interactions allowed for sharing of techniques that made an immediate impact on their work. The project provided educational opportunities that have impacted the professional development of students. For example, six courses were renovated that impacted more than 150 students at the PI's institution. In the first-year grant cycle, the project also provided 12 students with experimental and professional training for their academic development. Internships were created in the project that facilitated institutional exchange and student career development. This grant raised the profile of the research work creating invitations to the Investigators for seminars, conferences, and academic exchange. The section following dissemination lists the major events that were attended. In addition, there were countless phone calls, emails, and follow-up contacts with parties that would not otherwise have known of the program's work. Also importantly, the grant's attention attracted some donations to the overall program. How have the results been disseminated to communities of interest?Results and best practices identified through this work were made available through various educational and outreach efforts as below. Digital outreach: Regular Ginseng newsletters (Fall 2021, Spring 2022, and Fall 2022) were distributed to 200+ participants via email. A blog was posted on theSoil, Plant and Pest Center, UT Ag extension website to disseminate the information on labeled fungicides for ginseng. An Inaugural Podcast Episode was produced featuring Mr. Bob Beyfuss. A project member was interviewed by SeedBroadcast and WPLN about American ginseng. The story was later picked up by WBUR and aired nationally on NPR's Here & Now program. Workshop, growers meeting, field day, demo day: We organized and hosted Fall 2021 Ginseng workshop at Barfield Crescent Park, Murfreesboro, TN. Four invited speakers presented ginseng relevant harvest data, regulation, pest control, site evaluation, seed planting, and growth management techniques. Thirty participants learned how to use dedicated hand tools and planting techniques through expert demonstrations in the Park's natural forest using native seeds. Project team also participated in the annual Ginseng Field Day at Wausau, Wisconsin, hosted by the Ginseng Board of Wisconsin. We visited six large ginseng farms, visited field test plots, and met with approximately 20 growers in Wausau. Dr. Gao (PD) presented an organic ginseng cultivation workshop at the Organic Growers School 2022 Spring Conference in North Carolina with approximately 40 participants in attendance. Dr. Gao also spoke at Boring Ginseng Roots and Herbs annual growers' meeting and met with a group of growers, diggers, buyers, and representatives from herbal companies. The project team gave six presentations as shown in the following list in the Product section. In addition, PD and PIs have had over 20 meetings (in-person and virtual) with ginseng growers, stakeholders, and collaborators. Public outreach: The project team participated and presented American ginseng conservation in the Conservation Days event at Barfield Crescent Park on Earth Day. The project team members also presented American Ginseng's story on the National Mall in Washington D.C. for a week in June 2022 through an invitation from the Smithsonian Institution to participate in the Smithsonian's Folklife Festival. There we presented talks on forest pharmacy and conservation practices relevant to this endangered plant and engaged Festival attendees in one-on-one discussions. Note, participation was funded by the Smithsonian Institution and no USDA funds were used for this event. An educational component supporting teaching activities at MTSU, University of Tennessee, UVA-Wise, and Penn State University, as well as undergraduate research activities at these institutions, was developed. Six undergraduate and graduate courses with over 150 students at MTSU were renovated to include organic cultivation and sustainable agriculture elements (PLSO 1610 Elements of Plants Science (65 students), PLSO 4670 Herbs, Spices, and Medicinal Plants (34 students), PLSO 3350 Soil Fertility and Fertilizers (23 students), FERM 6450 Industrial Applications of Fermentation (5 graduate students), FERM 3710 Brewing, Distilling, and Fermentation Safety and Sanitation (7 students), FERM 1000 Introduction to Fermentation Science (18 students)). A total of 12 students (one Ph.D. student, five Master students, and six undergraduate students) at MTSU and UVA have been participating in research of this project and ten of them have presented at local, regional, or national conferences to report results from the project. In addition, this project provided internship opportunities for two interns who have been sent to the Soil, Plant, and Pest lab of UT Ag Extension in Nashville for training. What do you plan to do during the next reporting period to accomplish the goals?We plan to continue the research agenda during the next reporting period. As in the first reporting period, promising antifungal biocontrol agents were identified and tested in vitro. We will now further investigate the effectiveness of these agents in the greenhouse and field. Meanwhile, we will continue outreach efforts to promote sustainable organic production and certification to ginseng producers and continue to disseminate the results to stakeholders. **Impacts** What was accomplished under these goals? Objective 1: Evaluate the effectiveness of biological control microbial antagonists on fungal disease prevention and treatment for organic American Ginseng (AG) production. Accomplishments: 1. Collaborating with ginseng growers in Tennessee, Maryland, and Wisconsin, as well as academic researchers in pathology labs at Tennessee State University (TSU) and the University of Tennessee at Knoxville (UTK), we have collected more than 70 diseased AG plants from 5 locations in TN, MD, and WI, and isolated, cultured, and identified 21 fungal pathogens (both morphologically and molecularly) that specifically affect AG. To date, 3 species of Alternaria and 6 species of Fusarium have been isolated and identified from the diseased AG samples collected. A total of 102 healthy ginseng plants were prepared and used for fungal pathogenicity studies. These findings resulted in two manuscripts (one has been published) and were reported at the 2022 Tennessee Academy of Science annual conference. 2. Eight bacterial endophytes were isolated from regional AG genotypes and identified molecularly. The bacterial endophytes were screened against isolated pathogens for their antifungal potentials using dual culture assay, cell-free assay, and split plate assay methods. Two of the bacterial endophytes showed effectiveness against fungal pathogens. 3. We have summarized the fungicides labeled for use on ginseng in TN. A total of 138 labeled fungicides including organics were summarized in an excel spreadsheet. The summary results are available for the first time for the TN ginseng growers. The results were disseminated in the Fall 2021 ginseng workshop and a blog \"Fungal Pathogens of American Ginseng, Panax quinquefolius\" was posted on the Soil, Plant and Pest Center webpage on the University of Tennessee Ag extension website. Objective 2: Evaluate the effect of biological control microbial antagonists on soil physiochemical and biological conditions. Accomplishments: Collaborating with ginseng growers in Maryland and Wisconsin, we have collected a total of 40 rhizospheric soils of healthy and diseased AG plants. Metabarcode analysis was used to assess bacterial diversity and population size in the rhizospheric soil of healthy and diseased AG. A total of 4,372,803 sequences were generated among which 229,051 high-quality sequences were available for analysis. Soil analysis identified statistically significant differences between soil samples taken from healthy and diseased plants. One predominant bacterium species in the soil was found to be exclusively associated with healthy AG plants. In addition, we found that soil samples collected from two different cultivation methods (field and woods-cultivated) had a statistically significant difference in their microbiomes. These findings were reported at the 2022 American Society for Microbiology regional conference and a manuscript is under preparation. Objective 3: Evaluation of the antifungal effect of natural botanical extracts against AG's fungal pathogens. Accomplishments: We prepared 12 ethanol or aqueous extracts from selected plant species that have shown promising pathogen suppression properties either in growers' practices or reported laboratory research. We also evaluated their antifungal potential against the AG-specific pathogens using agar dilution assay and split plate assay. Among them, 6 botanical extracts showed effectiveness against AG-specific fungal pathogens. The preliminary results of this study were presented at the South Division of the 2022 American Phytopathological Society (APS) Annual Meeting and a manuscript is under preparation. Objective 4: Promote sustainable organic production and certification to local, regional, and national ginseng producers by emphasizing both the consumer's market preference and higher price yield the anticipated research solutions will deliver. Accomplishments: We hosted workshops and presented at local and regional conferences targeting ginseng producers where we promoted sustainable organic management techniques and certification. Specifically, we hosted a state-wide ginseng cultivation workshop in Tennessee with 30 participants, presented an organic ginseng cultivation workshop at the Organic Growers School 2022 Spring Conference in North Carolina, and also spoke at the 2022 New Crops for Southeast Agriculture Conference in Tennessee. Additionally, a market cost/benefit analysis for AG organic transition and production is under development. Objective 5: Disseminate and transfer the project results to stakeholders and public individuals. Accomplishments: Results and best practices identified through this work have been made available through various educational and outreach efforts. Please see the results disemmination section below for detailed activities. **Publications** - Type: Journal Articles Status: Submitted Year Published: 2022 Citation: Liyanapathiranage, P., Avin, F.A., Oksel, C., Swiggart, E., Gao, Y. , Baysal-Gurel, F. (Co-corresponding authors). First Report of Rusty Root of Panax quinquefolius Caused by Pseudomonas marginalis in Tennessee and the United States. Submitted to Plant Disease. - Type: Conference Papers and Presentations Status: Other Year Published: 2022 Citation: Gao, Y. Lopez, E.F., Baysal-Gurel, F., Eichas R., Swiggart, E. Fungal and Oomycete diseases in American ginseng (Panax quinquefolius L.) and current project evaluating organic disease control. 2022 American Phytopathological Society Annual Meeting - South Division. March 7-11, 2022. - Type: Conference Papers and Presentations Status: Other Year Published: 2022 Citation: 2. Lopez, E.F., Bernard, E.C., Gao, Y., Swiggart, E. Preliminary examination of Aphelenchoides sp. detected from American ginseng, Panax quinquefolius, in Tennessee. 2022 American Phytopathological Society Annual Meeting - South Division. March 7-11, 2022. - Type: Conference Papers and Presentations Status: Other Year Published: 2022 Citation: Gao, Y., Alnassari, K.A., Alnassari, A.A., Alnassari, F.A., Alnassari, Z.A. Moore, R., Zhang, M. Optimization of Ultrasound Assisted Extraction of Ginsenosides from Roots of Panax quinquefolius. 2022 ASP Annual Meeting. Charleston, South Carolina. July 21-24, 2022. - Type: Conference Papers and Presentations Status: Other Year Published: 2022 Citation: Oral presentation - Gao, Y. Growing ginseng in Tennessee. 2022 New Crops for Southeast Agriculture Conference. Nashville, Tennessee (hybrid mode). March 16-18, 2022. - Type: Conference Papers and Presentations Status: Other Year Published: 2022 Citation: Oral presentation - Gao, Y. Organic Ginseng Cultivation: Growing Appalachian Roots. Organic Growers School 2022 Spring Conference. Mars Hill University, North Carolina. March 19-20, 2022. - Type: Conference Papers and Presentations Status: Other Year Published: 2022 Citation: Oral presentation - 6. Bernard, E.C., Lopez, E.F., Gao, Y., Swiggart, E. Leaf lesions on American Ginseng associated with a foliar nematode, Aphelenchoide ssp., in Tennessee. The 61st Annual Meeting of the Society of Nematologists. Anchorage, Alaska, Sept 26-29, 2022. - Type: Websites Status: Published Year Published: 2021 Citation: Lopez, E.F. & Eichas, R. (2021). Fungal Pathogens of American Ginseng, Panax quinquefolius. https://soillab.tennessee.edu/fungal-pathogens-of-american-ginseng-panax-quinquefolius/ - Type: Websites Status: Published Year Published: 2021 Citation: Fall 2021 Ginseng Newsletter https://mtsu.edu/ginseng/docs/newsletter-2021-fall.pdf - Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Spring 2022 Ginseng Newsletter https://mtsu.edu/ginseng/docs/newsletter-2022-spring.pdf - Type: Websites Status: Published Year Published: 2022 Citation: Fall 2022 Ginseng Newsletter https://mtsu.edu/ginseng/docs/newsletter-2022-fall.pdf - Type: Journal Articles Status: Accepted Year Published: 2022 Citation: Avin, F.A., Liyanapathiranage, P., Shishkoff, N., Swiggart, E., Gao, Y. , Baysal-Gurel, F. (Co-corresponding authors). First Report of Powdery Mildew of American Ginseng Caused by Erysiphe heraclei in Tennessee and the United States. Plant Disease. https://doi.org/10.1094/PDIS-10-22-2310-PDN ** **

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Evaluating Environmental Impact of Organic Dairy Facilities Using Life Cycle Assessment Tools

Accession No.	1027033
Project No.	WIS04056
Agency	NIFA WIS\
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Proposal No.	2021-04814
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Performing Institution	UNIV OF WISCONSIN, 21 N PARK ST STE 6401, MADISON, WISCONSIN 53715-1218

NON-TECHNICAL SUMMARY

Organic systems have developed value based on improved sustainability. The organic dairy industry has sustained growth representing a significant portion of all US organic investments. For stakeholders to make informed decisions that impact industry growth, there is need for assessment and quantification of the environmental footprint of organic dairy systems. This project proposes to develop eight life cycle assessment regional models for organic dairy systems in the US. Outputs will provide baseline farm level environmental impact data on global warming potential (greenhouse gas emissions), eutrophication potential (nutrient losses), ammonia emissions, and resource depletion (energy, water, and land use) for numerous farm types across the eight regions. Models will be used to evaluate potential mitigation strategies to inform stakeholders of practices with high environmental mitigation potential and recommend those strategies for targeted outcomes (i.e., emissions reductions strategies). Researchers will also explore critical modeling assumptions that significantly impact environmental outcomes of organic dairy systems including selection of enteric methane predictive equations, allocation strategies, and methods used to quantify the global warming potential of methane. The outcomes from this objective will allow researchers making recommendations for methodological standardization and improved comparisons between studies. Project output will be used to inform stakeholders of pathways to improve environmental sustainability through extension and outreach channels as well as a critical relationship with Organic Valley. This work addresses priority two of the Organic Transition program by developing models to document ecosystems services from organic dairy with emphasis on climate change mitigation pathways of integrated livestock-cropping systems.

OBJECTIVES

This work aims to build upon an existing farm scale LCA model for organic dairies to evaluate sustainability metrics that can be used to guide on-farm practice implementation targeting reductions in environmental impacts related to global warming potential (greenhouse gas emissions and carbon sequestration), ammonia emissions, resource depletion (energy, land, and water use), and eutrophication (nutrient losses).Specific objectives include:Expand existing regional LCA models of organic dairy farms to cover the continental US for the environmental impacts of global warming potential (greenhouse gas emission and carbon sequestration), ammonia emissions, resource depletion (energy, land, and water use), and eutrophication (nutrient losses). Currently models have been developed for the Midwest/Great Lakes, New England, California, and Pacific Northwest regions. This work aims to develop additional regional LCA models using the developed framework for the Northeast, Mideast, Southwest, and Mountain regions to ensure all locations in the continental US have representative models to provide environmental impact data for all representative organic dairy systems. Assess environmental impacts of specific management practices in all US regions using the developed LCA modeling tools. This includes the identification and development of key variables that may be different for organic farms than previously modeled conventional farms (e.g., feed efficiency, replacement rate, diet composition) not currently available in the literature. Evaluate LCA methods to quantify environmental impact estimations, specifically enteric methane predictive equations, nitrous oxide emission factors from manure in pastures, allocation strategies, and methodologies for calculating the global warming potential of methane as they are important to the total estimations for greenhouse gas emissions from organic dairy farms. Develop extension materials and coordinate outreach activities. This includes developing fact sheets and other materials for each region. Researchers will also work with industry stakeholders to increase practice implementation and therefore environmental outcomes.

APPROACH

The proposed methods are detailed by objective below. Each objective includes the relevant scientific procedures, preliminary data, stakeholder engagement, and expected outcomes. Objective 1:LCA models were developed specifically for organic dairy systems at the University of Wisconsin-Madison by co-PI Aguirre-Villegas with the input from Organic Valley, a Cooperative of organic dairy producers and other university researchers. The US was divided into eight representative regions based on farm design and management practices using survey data and regional climate data. Regional models were developed to capture the effects of regionally specific environmental conditions and representative farm types and practices. To estimate these regional effects, data on environmental conditions, such as temperature and precipitation (collected from the National Oceanic and Atmospheric Administration), emissions from the electric grid (from the US Energy Information Administration) and energy matrix (from the US Department of Energy), crop yields and irrigation (from USDA-NASS national surveys), are collected from each state and averaged for each region based on the number of farms/milk production on each state. It is important to capture these differences as they are directly related to environmental impacts. In addition, it is important to evaluate the different practices adopted by the farm as they interact with environmental conditions. It is also common for many farms to select management and farm designs that fit their specific needs, and these practices are generally common to a region. This division allows for more accurate representation of organic dairy environmental impacts across the US. Each regional model tracks a variety of inputs through the system and allocates them to outputs that include milk, meat, and emissions (or losses) to the environment. The system boundaries for the LCA include all processing steps needed to produce milk on the farm. For this LCA, the functional unit is 1 kg (2.2 pounds) of fat and protein corrected milk (FPCM), adjusted to 4% fat and 3.3% protein. In each region, farm published data, survey data, expert and stakeholder opinion can be used to identify the most common practices for modeling purposes. Each location identified then requires detailed data collection for all model inputs needed to produce milk (starting from the extraction of natural resources to produce all energy and material inputs used by the farm until milk is produced at the farm gate). Inputs used by organic farms to be included in this assessment are water, energy (gasoline, propane, natural gas, fuel oil, diesel, and electricity) and materials (fertilizers, feed supplements, seeds, bedding, etc.). After identifying these inputs, inventory data is developed based on how much of each input is consumed at each farm layout and the emissions resulting from producing and consuming those inputs at the farm. Emission data from energy and materials will be generated with the SimaPro LCA Software (Pre-Consultants bv 2019). Biotic emissions, from the animals and manure management, are estimated with a series of process-based models and emission factors that relate management practices with environmental factors and physical characteristics of each system. A similar approach will be used to assess additional environmental impact categories for all regions and farm systems designs including resource depletion (including fossil energy, water use, and land use), and eutrophication potential. Besides emission sources, there are emission sinks in the form of carbon sequestration at organic farms as they rely mostly on grazing and forages for cow feed. For this project, the developed regional models using the detailed methodologies above will be expanded to cover all regions of the US, and the regional models further expanded to include additional functional units. This development will allow for environmental assessment of all regions in the US with organic dairy production. Objective 2.Farm management practices are the critical components of the system that producers can control to mitigate their environmental impacts. Using the models developed the environmental impacts of alternative management practices will be explored to determine their mitigation potential in all impact categories. These changes will be modeled to identify practices with the greatest mitigation potential with respect to the baseline environmental impacts developed in objective 1 and to evaluate if there are any trade-offs between environmental impact categories. This information can be used to guide design or management changes to achieve specific environmental outcomes and allow for quantification of those outcomes and to develop and track progress for mitigation targets. Objective 3.Among some of the most important of these decisions are the selection of models to predict enteric methane emissions, the allocation strategies used to partition environmental impacts between milk and meat, the selection of models or factors predicting nitrous oxide emissions from manure excreted on pastures, and more recently, the methods for quantifying the global warming potential of methane. For this study: In this work we propose to evaluate a variety of enteric methane predictive equations to determine the range of outcomes and the data requirements and interpretative ability to inform users of farm level interventions. This study will conduct a thorough literature review on nitrous oxide emissions from manure deposited on pastures and model alternative factors to the one suggested by the IPCC based on literature findings. The range of emission factors will be documented, logical bounds applied based on expert opinion, and the impact of this range provided using a sensitivity analysis. The results of this work will be able to provide insight of the importance of this variable and importance of further field research if needed. This study will apply different allocation strategies and clearly detail the methods used to assign the environmental impacts between milk and meat. It is important to analyze these different methods for transparency purposes and to facilitate the replication of the study and comparison to other studies evaluating the impacts of dairy systems. It is also important to show how results can vary based on these decisions, as the results from these types of studies might serve as the basis for local or regional environmental plans and targets. We will assess a proposed GWP* method which states that methane from biotic sources does not behave the same as methane from fossil sources. This study will assess the feasibility of including this method in environmental impact assessments of organic dairy farms and the overall impacts in the analyzed scenarios. Objective 4.Materials from this work will be directly translated to a variety of extension and outreach materials for use by stakeholders. The PIs have extension positions and will include the outcomes of this work in their outreach efforts beyond industry to other stakeholders such as producers, policymakers, and the public. This includes developing peer-reviewed extension materials and presentations to a wide number of stakeholders. The information will be translated for industry stakeholders including an existing partnership with Organic Valley and PI Silva\'s existing extension network for organic production including Westby Creamery, Stonyfield, and the Organic Trade Association Dairy Council. The information will be developed to be able to guide industry partners into making targeted reduction strategies for their milk production and to make direct practice recommendations to their producers through their sustainability initiatives. Progress 09/01/23 to 08/31/24 Outputs Target Audience:Our target audience included organic dairy producers who are looking to improve sustainability metrics, particularly thoseimplementing the practices recommended to reduce GHG emissions, industry partners particularly Organic Valley to guide industry GHG reduction targets and strategies for mitigation, and policymakers to inform on potential for emissions mitigation in organic systems. We also targeted other researchers to inform them on organic dairy practices and modeling as well as producer tools to help guide tool development that assess GHGs to include organic practices. Finally, we targeted businesses that work in certifying sustainable practices in industry and other industries that have reached out in the extended industry using dairy products as they are interested in integrating the outputs into their sustainability planning. We also won an award highlighting the impact of our research. 2024 Most Impactful Organic Research Finding Winner, Organic Oscars Natural Products Expo West, Anaheim, CA, March 14, 2024 Hosted by The Organic Center and Organic Voices Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?A graduate student has been trained on the project, Caleb Besson, in Agricultural Engineering learning extensive modeling skills and critical information on organic dairy production systems as well as working with a stakeholder team. The student has successfully defended their M.S. thesis and is now graduated (Summer 2024 graduation). How have the results been disseminated to communities of interest?The results have been shared extensively with stakeholders. This includes Organic Valley as well as other producers engaged through various outreach events. A surprising aspect of the project has been the interest from sustainability teams at companies who use dairy products and their interest in engaging and integrating data into their sustainability planning. What do you plan to do during the next reporting period to accomplish the goals?We have outlined a number of priorities for the next year: 1. Submit the graduate student work on accounting tools for organic dairies for peer review and publication as well as share results with stakeholders. 2. Complete additional modeling on bedded pack systems. 3. Complete additional modeling (and publish a paper) expanding the assessment of mitigation practices in more detail and including a sensitivity analysis. 4. Complete LCA modeling with expanded system boundaries relevant to organic dairy production systems including: renewable energy production and sale additional animal types additional crop production Impacts What was accomplished under these goals? 1. Completed the LCA for all regions in the U.S. A paper covering the additional regions is currently under review. Complete! 2. We have completed the assessment of management practices for mitigation for all regions and have included this information in the paper being published. Wtth ongoing discussions with stakeholders, they would like even more practices modeled so we have prioritized expanding modeling even more mitigation practices over the next year. 3. We have completed this assessment in the regions modeled around the U.S. and included the results in the paper that is in review. Most significant finding is that modeling choices have as much if not greater impact on the greenhouse gas emissions accounting than the actual practices used highlighting the importance of standard accounting methods. 4. We continue to serve stakeholders by providing Organic Valley with information to support their producers in implementing the greenhouse gas mitigation practices outlined, (e.g., additional modeling on bedded packs and composting, additional information on evaluating manure separation systems), we meet monthly with Organic Valley representatives to ensure continued dialogue and support. We alsoparticipatein numerous producer and industry conferences and meetings to share project output as well as get guidance on project direction.We have also been working with a variety of industry partners that are looking to integrate the data into their sustainability plans/metrics, this includes adjusting output to meet stakeholder needs for accounting format. Publications Type: Theses/Dissertations Status: Published Year Published: 2024 Citation: Besson, Caleb. 2024. EVALUATION OF STAKEHOLDER TOOLS, COMET-FARM AND COOL FARM TOOL, TO ESTIMATE GREENHOUSE GAS (GHG) EMISSIONS FROM ORGANIC DAIRY SYSTEMS. Masters Thesis Submitted to the University of Wisconsin-Madison. Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Larson, R.A. 2024. Managing Manure for the Climate. Marbleseed 35th Annual Organic Farming Conference, February 22-24, 2024 La Crosse, WI. Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Besson, C, H.A. Aguirre-Villegas, and Larson, R.A. 2024. Evaluating stakeholder tools, COMET-Farm & Cool Farm Tool, to estimate GHG emissions from organic dairy systems. Marbleseed 35th Annual Organic Farming Conference, February 22-24, 2024 La Crosse, WI. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Aguirre-Villegas, H., R.A. Larson, and C. Besson. 2023. Ammonia emissions inventory of different management practices and dairy farm settings. 2023 North American Manure EXPO, August 9 & 10, 2023, Arlington, WI. Type: Journal Articles Status: Under Review Year Published: 2024 Citation: Horacio A. Aguirre-Villegas, Nicole Rakobitsch, Michel A. Wattiaux, Erin Silva, Rebecca A. Larson. 2024. Environmental Assessment of Organic Dairy Farms in the US: Mideast, Northeast, Southeast, and Mountain Regions. Cleaner Environmental Systems, In Review. Type: Other Status: Published Year Published: 2024 Citation: 2024 Most Impactful Organic Research Finding Winner, Organic Oscars Natural Products Expo West, Anaheim, CA, March 14, 2024 Hosted by The Organic Center and Organic Voices Progress 09/01/22 to 08/31/23 Outputs Target Audience:Our target audience included organic producers who were implementing the practices recommended to reduce GHG emissions, industry partners particularly Organic Valley to guide industry GHG reduction targets and strategies for mitigation, and policymakers to inform on potential for emissions mitigation in organic systems. We also targeted other researchers to inform them on organic dairy practices and modeling as well as producer tools to help guide tool development that assess GHGs to include organic practices. Finally, we targeted businesses that work in certifying sustainable practices in industry. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?A graduate student is learning the LCA models, as well as stakeholder models, and learning research connection to industry and stakeholder needs. He has also presented numerous posters on the data. How have the results been disseminated to communities of interest?Yes! We have presented at many conferences and worked directly with Organic Valley to integrate practices in a regular basis. What do you plan to do during the next reporting period to accomplish the goals?We have monthly meetings with stakeholders and also have been engaging with other organic projects (one specific project based out of NY). These connections have proven very useful in guiding next steps. With the models complete this calendar year (the major chunk of this work) we can then focus the last year on really evaluating practices, and integrating needs from stakeholders. Impacts What was accomplished under these goals? 1. Currently models have been developed for the Midwest/Great Lakes, New England, California, Pacific Northwest, Mideast, and Northeast. We have completed databases of organic dairy farms types for all regions in the U.S.(the most time consuming component).We are working to complete the Southwest, and Mountain regions currently (end of calendar year goal) and that will complete all modeling requirements. Plans are to publish these in the coming months. 2. We have developed some of these practices in the above models from objective one. In 2024, with the models complete we plan to expand this based on the information of practices received from stakeholders including Organic Valley. 3. This work is planned for 2024. 4. We developed three fact sheets on ammonia emissions that include organic dairy systems. We have also worked with Organic valley to integrate practices into existing farms to mitigate GHG emissions. We have had numerous presentations around the country and have had an overwhelming interest from industry partners on the information, we are working to provide as much information as we can to those who can integrate practices to drive outcomes of GHG reduction.A grad student has also been modeling the farms from Obj. 1 in cool farm tool and comet to provide ends users feedback on tools and to give tool designers critical information to improve estimates for organic dairies. Publications Type: Journal Articles Status: Published Year Published: 2022 Citation: Aguirre-Villegas, H.A., R.A. Larson, N. Rakobitsch, M.A. Wattiaux, & E. Silva. 2022. Farm Level Environmental Assessment of Organic Dairy Systems in the U.S. Journal of Cleaner Production, 363. https://doi.org/10.1016/j.jclepro.2022.132390 Type: Journal Articles Status: Published Year Published: 2023 Citation: Aguirre-Villegas, H.A., C. Besson, & R.A. Larson. 2023. Modeling ammonia emissions from manure in conventional, organic, and grazing dairy systems and practices to mitigate emissions. Journal of Dairy Science, https://doi.org/10.3168/jds.2023-23782 Type: Other Status: Published Year Published: 2022 Citation: Besson, C.R., H.A. Aguirre-Villegas, & R.A. Larson. 2022. Sources and Impacts of Ammonia Emissions. University of Wisconsin-Extension, Publication No. A4192-010, I-11-2022. Type: Other Status: Published Year Published: 2022 Citation: Besson, C.R., H.A. Aguirre-Villegas, & R.A. Larson. 2022. Ammonia Emissions from Manure Systems on Dairy Farms in Wisconsin. University of Wisconsin-Extension, Publication No. A4192-011, I-12-2022. Type: Other Status: Published Year Published: 2023 Citation: Besson, C.R., H.A. Aguirre-Villegas, & R.A. Larson. 2023. Mitigating Ammonia Emissions using Dairy Manure Management Practices. University of Wisconsin-Extension, Publication No. A192-12, I-02-2023. Type: Conference Papers and Presentations Status: Published Year Published: 2023 Citation: Larson, R.A., H.A. Aguirre-Villegas, N. Rakobitsch, M.A. Wattiaux, & E. Silva. Environmental Assessment and Carbon Sequestration Potential of Organic Dairy Systems in the U.S. 2023 Minnesota Organic Conference, January 6, 2023 St. Cloud Minnesota. Type: Conference Papers and Presentations Status: Published Year Published: 2022 Citation: Aguirre-Villegas, H.A. 2022. Green House Gas Emissions on Organic Dairy. University of Vermont Extension Webinar Series, March 2, 2022. **Progress** 09/01/21 to 08/31/22 **Outputs** Target Audience:The target audience for this reporting period has been researchers and the organic dairy industry. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? A graduate student had begun to learn to develop life cycle assessment models for organic dairy systems. How have the results been disseminated to communities of interest? We have been working with Organic Valley and are exploring working with the Danone. What do you plan to do during the next reporting period to accomplish the goals? We are planning to complete the expansion of the regional assessments. This will allow us to publish the entire LCA model for the U.S., then we can start the followup assessments in later years. **Impacts** What was accomplished under these goals? Currently models have been developed for the Midwest/Great Lakes, New England, California, and Pacific Northwest regions. This work aims to develop additional regional LCA models using the developed framework for the Northeast, Mideast, Southwest, and Mountain regions to ensure all locations in the continental US have representative models to provide environmental impact data for all representative organic dairy systems. ACCOMPLISHMENTS: We have begun to expand the work to additional regions within the United States beginning with the MidEast. The remaining regions are to be completed over the next year. ACCOMPLISHMENTS: Will be completed after the regional expansion is complete. Have developed a list of practices with Organic Valley to evaluate. ACCOMPLISHMENTS: Will be completed after the regional expansion is complete. ACCOMPLISHMENTS: Will be completed after the regional expansion is complete. Impact-Organic systems have developed value based on improved sustainability. The organic dairy industry has sustained growth representing a significant portion of all US organic investments. For stakeholders to make informed decisions that impact industry growth, there is need for assessment and quantification of the environmental footprint of organic dairy systems. This project proposes to develop regional life cycle assessment models for organic dairy systems to provide environmental impact data on global warming potential (greenhouse gas emissions and carbon sequestration), eutrophication potential (nutrient losses), ammonia emissions, and resource depletion (energy, water, and land use) for numerous farm types across the entire US. This data can then be used to help develop a pathway to improved sustainability, guide producers in developing mitigation strategies and sustainability investments, provide scientific support for policymakers in developing sustainable initiatives and regulations, guide industry targeted environmental standards and reduction metrics, and finally provide scientific data for consumers to make product comparisons. This project will not only seek to produce meaningful research output for stakeholders but will also explore critical modeling assumptions that significantly impact environmental outcomes of organic dairy systems including selection of enteric methane predictive equations, allocation strategies, quantifying nitrous oxide emissions from manure deposited on pastures, and methods used to quantify the global warming potential of methane. Outcomes of these research methodology objectives will allow researchers to make informed recommendations for methodological standardization of environmental impacts from organic dairy and improved comparisons between studies in the future. Project output will be used to inform stakeholders of pathways to improve environmental sustainability through extension and outreach channels as well as a critical relationship with Organic Valley to develop targeted emissions reductions strategies. **Publications** - Type: Conference Papers and Presentations Status: Accepted Year Published: 2022 Citation: 4.Aguirre-Villegas, H.A., R.A. Larson, N. Rakobitsch, M.A. Wattiaux, & E. Silva. 2022. The Role of Manure for Dairy Carbon Neutrality Targets: An Environmental Assessment of Organic Farms. Livestock and Poultry Environmental Learning Community Waste to Worth 2022: International Conference on Livestock and Poultry Environmental Quality, April 19-22, 2022, Maumee, OH.

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Transitioning to Organic Day-neutral Strawberry Production in the Upper Midwest - a Systems Approach

Accession No.	1027040
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Performing Institution	UNIV OF WISCONSIN, 21 N PARK ST STE 6401, MADISON, WISCONSIN 53715-1218

NON-TECHNICAL SUMMARY

The long-term goal of this multi-state and multi-disciplinary project is to increase and sustain organic day-neutral strawberry production in the Upper Midwest. This project addresses program Priority 4, developing practical information and tools to help producers overcome barriers to organic transition and Priority 1, understanding the effects of organic practices on weeds, pests and diseases for better management. Strawberries represent the largest fruit crop in MN and the third largest fruit crop in WI. However, organic strawberry production is negligible in the region, despite interest among growers, excess demand and premium prices for this product at local markets. A major limitation growers face in transitioning to organic strawberry production is linked to the perennial matted row production system almost exclusively used in the region for strawberry production, which increases weed, insect, and disease pressure over multiple seasons that are challenging to control with current organic practices. This project proposes to implement a systems approach to overcome challenges faced by growers when transitioning to organic strawberry production in the Upper Midwest by: 1) shifting from a perennial to an annual production system; 2) generating research-based information on organic-approved management practices to reduce insect, disease, and weed pressure; 3) evaluating insect and disease pressure during the growing cycle; and 4) determining the profitability on small-scale farms.

OBJECTIVES

Thegoal of this project is to increase and sustain organic strawberry production in the Upper Midwest by: 1) transitioning from the traditional perennial matted row system to annual production system using day-neutral strawberry cultivars, 2) generating research-based information on organic-approved management practices for annual day-neutral strawberry production, and 3) evaluating the profitability of growing organic day-neutral strawberries.Specific Objectives are:Objective 1:Determine plant growth, yield, and fruit quality of day-neutral strawberries grown in four film-based mulches.Objective 2:Determine the impact of film-based mulches on insect pests and pollinators in strawberries.Objective 3: Evaluate the pressure of insect pests and diseases in day-neutral strawberry systems from planting to harvest.Objective 4:Estimate the break-even prices and farm-level profitability for organic day-neutral strawberries under low and high pest pressure.

APPROACH

Experimental Design-Randomized complete block split-plot consisting of four film-based mulch treatments as the main plot and two pest control treatments as split plots, replicated four times.Treatments-White on black polyethylene mulch;Black plastic polyethylene mulch;Reflective metallic polyethylene mulch;WeedGuardPlus cellulosic biodegradable maroon mulch.Objective 1:Determine plant growth, yield, and fruit quality of day-neutral strawberries grown in four film-based mulches.Dry biomass of strawberry plants will be determined the week after the conclusion of harvest. Plants per subplot will be harvested and separated by roots, leaves (petioles included) and dried at 70 °C for 5 days. Plant canopy diameter will be measured in a selection zone consisting of 28 plants in the center of each split plot replicate. Plant survival will be evaluated within the first 4 weeks after planting by counting the number of plants alive per plot replicate.Plots will be harvested twice each week, but only once each week for the first and last harvest weeks of each season, when yields are lower. During each harvest, all berries picked within a selection zone, consisting of the interior 28 plants within each split plot replicate, will be weighed for experimental unit yield. Unit yield from each of the two harvests a week will be combined to calculate weekly yield per unit. Twenty berries in each selection zone will be randomly selected, weighed, and divided by 20 to gauge average berry weight for that unit. Three fruit samples will be collected for quality analysis: early August, mid-September, and early October. Five berries from the selection zone of each treatment/pest control split plot will be selected randomly and measured for total soluble solids and titratable acidity using digital refractometer and titration system, respectively. During three harvest dates during the growing season, 15 berries per treatment will be packed in plastic clamshells and stored at 4°C, 80- 85% RH for 15 days. Fruit temperature will be recorded for a subsample of the berries before storage. All fruit quality parameters will be analyzed during 0, 5, 10 and 15 days of interval. Fruit weight loss, fungal decay, and insect infestation (SWD larvae) will be recorded before and during each storage interval.Visual observations of rips, tears, and holes will be recorded to assess mulch deterioration, as percent visual cover (PVC) of the soil twice a month from planting to the end of harvest each year. PVC and weed cover will be determined using a 1 m2area grid in the same selection zone used for harvest and plant growth measurements. The scale of evaluation for mulch deterioration will consist of 100% rating for an intact mulch film.Objective 2:Determine impacts of film-based mulches on insect pests and pollinators in strawberriesMajor insect pests will be sampled including spotted-wing drosophila (SWD), tarnished plant bug (TPB) and thrips. Sampling will be done every other week frommid-July until the end of the harvest period. Berries will be collected from each non-sprayed plot and placed in plastic bags, macerated, and submerged in sugar water, larvae that float to the surface of the water will be counted. We will use vacuum samplingto capture adult and immature TPB, sampling from 25 plants in the center of each non-sprayed plot. Damage caused by TPB will be assessed once per week at harvest. Thrips will be sampled with blue sticky cards measuring 10 cm x 25 cm, containing dashed grids forming 1 cm2 squares. Cards will be placed in each non-sprayed row approximately 10 m apart (2 cards/row).Sampling will occur every other week. Vacuum sampling will be conducted on flowers to assess the abundance and diversity of bees and abundance of syrphid flies present on flowers. Each unsprayed row will be vacuumed with handheld DC insect vacuum (BioQuip). Samples from each row will be bagged and frozen for later counting and identification to bee species in the laboratory. Syrphid flies will be counted but not identified to species. Direct observations (WI only) of insect visits on flowers will be conducted every other week on alternating weeks from vacuum sampling in each unsprayed row. Observations will consist of 10 min bouts focusing on five plants in the middle of each row.Objective 3:Evaluate insect and disease pressure and provide control recommendations in organic day-neutral strawberry systems. Number of symptomatic plants per treatment will be determined, and individual symptomatic plants will be assessed for disease type. For foliar diseases, number of lesions (spots) per leaf or number of blighted leaves will be enumerated for symptomatic plants. For fruit diseases, the number of symptomatic fruits will be quantified per plant. Belowground plant diseases will be quantified based on visual observation of aboveground symptoms (i.e., wilting).For fungal pathogens, Howler and Regalia will be used to control diseases of day-neutral strawberries. For insects, sampling will be conducted weekly on ten plants in the middle of each row using visual inspections for damage symptoms, including number of clipped flower buds (strawberry bud weevil) and number of spittle masses (spittle bug). Sweep nets (tarnished plant bug), berry infestations via salt floats (spotted-wing drosophila), and in situ number of individuals per plant (thrips, spider mites, leafhoppers, sap beetles) will be assessed. Entrust and Pyganic will be used to control populations based on established economic thresholds. Objective 4:Estimate the break-even prices and farm-level profitability for organic day-neutral strawberries under low and high pest pressure. Enterprise budgeting will be applied to explore the impact of production systems (perennial matted row or PMR vs. day-neutral strawberry or DNS), alternative mulches (film-based alternatives) and total marketable yield on strawberry profitability in the Upper Midwest.An enterprise budget will be developed for organic PMR strawberries using recommended material and labor inputs. A partial budget analysis will then be applied to the full enterprise budget to explore changes in strawberry cultivar (from PMR to DNS) and film-based mulch alternatives on net returns.A partial budget will be calculated for each of the mulch alternatives by measuring changes in variable costs such as the cost of plants, mulch and labor as well as changes in marketable yield. The partial budget will inherently capture the effects of a longer harvest season yield (6 weeks vs. 12 weeks) and seasonal changes in price as well as differences in the impact of pest, weed and disease pressure among the mulch alternatives. Borrowing information from the budgets, we will calculate break-even prices and test the robustness of the final results using a sensitivity analysis. The sensitivity analysis will explore the impact of price variation on net returns using wholesale and direct market pricing.Enterprise budget material input estimates will be pulled from the Farm Business Management regional, \"Crop Enterprise Analysis, Strawberries, 2012-2018\", and \"Strawberries (PYO June-bearing) - Production Year Budget, 2014.\" Input costs will be updated using market values available at the time for mulch alternatives included in the study. Labor will be valued using the USDA NASS seasonal \"Farm Labor\" reports for the Midwest states. Yield data for the film-based mulch treatments will be compiled in Objective 1. Yields for traditional PMR systems will be obtained from field trials conducted in MN (Petran et al., 2017). Organic strawberry values will be quantified using seasonal weighted average retail price data available bi-weekly from USDA Agricultural Market News Service, \"Weekly Advertised Fruit & Vegetable Prices, Midwest.\" Prices will be adjusted downward to reflect wholesale and farmers market pricing. Progress 09/01/21 to 12/31/24 Outputs Target Audience:Target audience is specialty crop farmers, in particular organic vegetable farmers, conventional and organic strawberry farmers, scientist working in organic production systems, small fruit research, pest and disease management, and agricultural economics, extension personnel, and crop advisors. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?This project provided valuable training and professional development opportunities for a diverse group of participants at multiple levels. Over the course of the project, we trained and supervised a total ofseven undergraduate students, who gained hands-on experience in both field and laboratory settings. Their training included organic day-neutral strawberry production management practices such as planting, irrigation, fertilization, weed management, pest and disease scouting, and post-harvest fruit quality evaluation. In addition, students participated in lab-based activities, including sample processing, data collection, and data management, contributing to both research and extension outcomes. One of the undergraduate trainees was a visitingREEU (Research and Extension Experiences for Undergraduates)student from Red Lake Nation College, a public tribal land-grant community college located on the Red Lake Indian Reservation in Red Lake, Minnesota. This student was mentored in both research and field production practices related to organic strawberry systems. This project also supported the training and professional development ofJarret Miles-Kroening, a Master\'s of Science graduate student at the University of Wisconsin-Madison. Jarret successfully completed his M.S. thesis on organic day-neutral strawberry production as part of this project. His research contributed significantly to the project\'s outcomes, and through this work, he developed expertise in experimental design, data analysis, and both field and lab research methodologies. Additionally, Jarret gained valuable experience in presenting research findings to grower audiences and academic peers. As part of their professional development, one of our graduate students and an undergraduate summer intern attended theWisconsin Berry Growers Associationfield day onJuly 12, 2022, in Poynette, WI. This experience provided them with opportunities to interact directly with growers, observe organic management practices in commercial settings, and engage with industry stakeholders. Additionally,Leah Worth, an undergraduate student, received training in video production usingWeVideoand developed a short outreach video focused on organic production of day-neutral strawberries. This helped enhance her science communication skills and broadened the project\'s outreach impact. Finally,Ariana Abbrescia, a temporary limited-term employee at UW-Madison, was trained in all aspects of organic strawberry production, including crop management, pest and disease monitoring, and post-harvest evaluation. These training experiences not only enhanced the technical skills of the participants but also supported their professional development by providing opportunities for engagement with growers, hands-on research experience, and science communication. How have the results been disseminated to communities of interest?The results of this project have been widely disseminated through a variety of outreach and engagement activities aimed at organic and conventional specialty crop growers, agricultural professionals, researchers, and broader community audiences throughout the Upper Midwest and beyond. Our dissemination strategy included in-person events, virtual learning opportunities, publications, multimedia resources, and direct engagement with growers to ensure broad accessibility and practical impact. In 2023, we hosted two field days to demonstrate organic day-neutral strawberry production practices. One was held on August 31, 2023, at the West Madison Agricultural Research Station with approximately 25 growers in attendance. The second field day took place on July 25, 2023, at the University of Minnesota Organic Field Day in St. Paul, MN, with around 60 growers participating. In 2022, the project was featured during the Organic Specialty Crops Field Day at the University of Minnesota St. Paul campus on July 26, with 84 attendees, including farmers, master gardeners, and agriculture-related professionals. Post-event evaluations indicated that 88% of participants gained substantial new knowledge. Across these events, field days addressed key production topics, including soil fertility, irrigation management, insect pest control, disease scouting, weed management, and post-harvest fruit quality. Attendees consistently rated these events highly and reported plans to adopt new practices based on what they learned. We convened our Grower Advisory Panel three times over the course of the project: November 18, 2021; April 7, 2023; and August 8, 2024. During these meetings, we presented project updates, preliminary and final results, and collected feedback from board members on production practices and research priorities. Growers shared practical recommendations that we incorporated into our management strategies, including planting organic rye grass and clover in alleyways to reduce weed control labor, reducing runner tipping frequency to once a week, and switching to organic fertilizer blends with higher nitrogen content to improve plant vigor. The advisory board members expressed enthusiasm about the project\'s progress and outcomes and provided valuable input on how to disseminate results more broadly. The August 2024 meeting included growers such as Andy Petran of Twin Cities Berry Company, Sarah Holle of Mill City Farmers Market, and Janssen Hang of the Hmong American Farmers Association, who helped shape our outreach approach for both organic and conventional producers. We delivered several webinars targeting specialty crop growers in the Midwest as part of the Cold Climate Webinar Series and the Organic Commercial Fruit Production Strategies for the Midwest Webinar Series. These were organized in collaboration with UW-Madison, University of Minnesota, Iowa State University, and University of Illinois. Topics covered included organic insect management, disease management, organic certification, and marketing strategies. Archived recordings of these webinars have received hundreds of views, extending access beyond the live events. We shared project findings through multiple conference presentations and stakeholder events. Presentations were delivered at the Great Plains Growers Conference, the Wisconsin Fresh Fruit and Vegetable Annual Conference, the Hmong American Growers Association Annual Farmer Training, and the Minnesota Fruit and Vegetable Growers Association Annual Conference. Scientific presentations were delivered at the American Society for Horticultural Science Annual Conference in Honolulu, HI, in September 2024. Additionally, presentations were made at the Minnesota Department of Agriculture Organic Conference in January 2023 and at the Growing Wisconsin Conference in January 2024. We presented research posters highlighting key findings at the Marbleseed Organic Farming Conference in February 2024 and at the UW-Madison Day at the Capitol Graduate Research Showcase in April 2024. These posters covered topics such as the evaluation of film-based mulches to promote day-neutral strawberry production and the assessment of organic control methods for spotted-wing drosophila and their economic viability. We published over 20 articles on insect and disease scouting for organic day-neutral strawberry production in the Wisconsin Fruit News, which reaches more than 800 subscribers, including commercial growers and master gardeners. Additionally, PD Amaya Atucha developed a feature video with the Organic Farming Research Foundation that spotlighted the project and its impact on organic agriculture in the Upper Midwest. The project team also produced several demonstration videos covering key production practices. These included videos on weed management in organic day-neutral strawberries, mulch removal in organic strawberry production, and diagnosing and managing diseases in organic day-neutral strawberries. These videos were shared widely and have collectively accumulated over 1,000 views to date. Project team members participated in podcasts and interviews to further expand outreach efforts. Margaret Rogers was a guest on the Strawberry Chat Podcast, hosted by Dr. Wenjing Guan at Purdue University, where she was joined by grower Andy Petran to discuss day-neutral strawberry production. Gigi DiGiacomo was interviewed by Tom Young of the University of Maryland to discuss the economics of day-neutral strawberry production. This multi-pronged outreach approach successfully connected our research with a broad audience of growers, educators, agricultural professionals, and the general public, increasing awareness and adoption of organic day-neutral strawberry production systems. It has also fostered greater interest in organic agriculture and sustainable fruit production practices across the Upper Midwest. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? Objective 1:Determine plant growth, yield, and fruit quality of day-neutral strawberries grown in four film-based mulches. We conducted multi-year field trials in Wisconsin and Minnesota to evaluate four mulch types: white-on-black plastic, black plastic, reflective metallic plastic, and biodegradable crepe paper. Metallic mulch consistently produced the highest yields in Wisconsin, while paper mulch had no significant impact. Fruit quality assessments showed berry weight varied by mulch and location, with paper mulch producing the largest berries in Wisconsin. Postharvest evaluations indicated that metallic mulch reduced fruit weight loss and fungal decay during cold storage. These findings provide organic growers with science-based recommendations for mulch selection that improve yield and fruit quality while promoting climate-smart practices. Results have been shared with growers via field days and extension materials. Objective 2:Determine the impact of film-based mulches on insect pests and pollinators. We monitored tarnished plant bugs (TPB), western flower thrips (WFT), and spotted wing drosophila (SWD), along with pollinator visits. Reflective mulch had the lowest WFT numbers and fruit bronzing, while white-on-black mulch had the highest. TPB pressure was high across treatments, and mulch type did not significantly reduce TPB populations. Organic insecticides were applied based on thresholds but did not fully reduce TPB-related unmarketable fruit, highlighting the need for improved control strategies. Syrphid flies were the most frequent floral visitors, and pollen analysis confirmed their role as key pollinators. Mulch type had little effect on pollinator diversity or pollen loads, suggesting growers can optimize for pest control without compromising pollination services. Objective 3:Evaluate pest and disease pressure from planting to harvest. Weekly scouting in Wisconsin and Minnesota showed that disease pressure was relatively low across all mulch treatments. Common Leaf Spot and Phomopsis Leaf Blight were observed but did not reach treatment thresholds, and no fungicides were applied. TPB and WFT were the most damaging insect pests, with mulch selection influencing WFT incidence. SWD presence was minimal and not a major contributor to unmarketable fruit. While reflective mulches offered some protection against WFT, additional strategies are needed to manage TPB effectively. To support growers, we published 19 pest and disease scouting updates in the Wisconsin Fruit News and developed an educational video on organic strawberry disease management. Objective 4:Estimate break-even prices and profitability under low and high pest pressure. We conducted enterprise budget analysis comparing four mulch treatments. All mulches resulted in positive net returns when berries were sold at direct-market prices. Metallic plastic mulch generated the highest net returns. Biodegradable paper mulch had higher costs and required additional labor, making it less profitable under lower-yield scenarios. Profitability was most sensitive to yield rather than price fluctuations. These findings help growers make informed decisions about mulch selection and investment in organic strawberry production. Results were shared through field days, conference presentations, and extension publications, contributing to economic sustainability in organic farming. Publications Progress 09/01/23 to 08/31/24 Outputs Target Audience:Target audience is organic horticultural crop producers, new and existing strawberry producers, includes farmers from underrepresented audiences. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided?Leah Worth (technical professional) has received training on video production using WeVideo to make a short outreach video on organic production of day-neutral strawberries as part of this project. How have the results been disseminated to communities of interest?We hosted a virtual meeting with our advisory grower panel August 8, 2024, attendees included: Andy Petran- Twin Cities Berry Company; Sarah Holle, Senior Manager of Programs and Operations Mill City farmers market, Janssen Hang- The Hmong American Farmers Association. The team provided an overview of all activities completed and preliminary results of data analysis. The panel was very enthusiastic about the results of the project and provided feedback on how to continue to disseminate the results of the project. The team deliver the following oral presentation on the results of the study to stakeholders (organic and conventional specialty crop growers) and the broader scientific community: Guédot C.,Lannan M,Miles-Kroening J.,Atucha A. Diversity and abundance of insects visiting grape and strawberry flowers in Wisconsin. American Society for Horticultural Science Annual Conference, Honolulu, HI, September 23-27, 2024. Rogers, M., Miles-Kroening, J., Gullickson, M., Burkness, E., DiGiacomo, G., Guedot, C., Atucha, A., Holland, L.Effects of Mulch Type on Day-Neutral Strawberry Yield and Quality in an Organic Production System in the Upper Midwest. American Society for Horticultural Science Annual Conference, Honolulu, HI, September 23-27, 2024. Atucha, A. and Miles-Kroening, J. (2024). Organic Day-Neutral Strawberry Production. Growing Wisconsin Conference. Wisconsin Dells, Wisconsin. January 22, 2024. Holland, L. (2024). Day-Neutral Strawberry Disease Management. Growing Wisconsin Conference. Wisconsin Dells, Wisconsin. January 22, 2024. Rogers was part of a panel that included Andy Petran, strawberry grower and member of our project advisory committee on Strawberry Chat, a podcast hosted by Dr. Wenjing Guan at Purdue University and available on Spotify.https://creators.spotify.com/pod/show/strawberrychat/episodes/Day-Neutral-Strawberry-Production-I-Episode-16\--Nov\--10-2023-e2bp6vb DiGiacomo, G. Economics of day-neutral strawberry production. April 26, 2024. Interview by Tom Young, University of Maryland. We published 5 news articles on insect and disease scouting for organic day-neutral strawberry production. These articles were published in the Wisconsin Fruit News that reaches over 800 subscribers. PD Amaya Atucha developed a video with the Organic Farming Research Foundation highlighting the project. Federal support is bringing new production systems and researchers to organic agriculture in the upper Midwest.https://ofrf.org/news/organic-researcher-spotlight-amaya-atucha/ The team developed one demonstration video on Diagnosing and Managing Diseases in Organic Day-Neutral Strawberries (471 views).https://youtu.be/nZlkWIKDgP0?si=tDAHZnVmnPM-Ghat During 2024, we delivered a webinar series on \"Organic Commercial Fruit Production Strategies for the Midwest\" through the Cold Climate Webinar Seriesorganized by UW-Madison, University of Minnesota, Iowa State University, and University of Illinois. Rihn, A. (2024) Marketing for Organic Fruit.Organic Commercial Fruit Production Strategies for the MidwestWebinar Series organized by University of Wisconsin Madison.https://youtu.be/8aX-7Y7iERQ?si=aaCnJit6owMQD5da. March 11, 2024. Holland, L. and Slack, S. (2024) Marketing Disease Management.Organic Commercial Fruit Production Strategies for the MidwestWebinar Series organized by University of Wisconsin Madison.https://youtu.be/M5tVZLqccB4?si=GNXVt6YyRS4Tj2Sm. March 4, 2024. Guedot, C. and Athey, K. (2024) Organic Insect Management.Organic Commercial Fruit Production Strategies for the Midwest Webinar Series organized by University of Wisconsin Madison.https://youtu.be/7TS5e5oGMCk?si=qZUv9WT3rNVGyq2r. February 26, 2024. Fillius, D. (2024) Organic Certification.Organic Commercial Fruit Production Strategies for the MidwestWebinar Series organized by University of Wisconsin Madison.https://youtu.be/tOJn8DTu440?si=o7KAA_HneUi_zKit. February 12, 2024. Posters presented at stakeholder and scientific meetings: Miles-Kroening J., Atucha A., Guédot C. Evaluation of Film-Based Mulches to promote Day-Neutral Strawberry Production System in the Upper Midwest. Graduate Research Showcase: UW-Madison Day at the Capitol, Madison, WI. 17 April 2024. Miles-Kroening J., Atucha A., Guédot C. Evaluation of Film-Based Mulches to promote Day-Neutral Strawberry Production System in the Upper

Midwest. Marbleseed Organic Farming Conference, La Crosse, WI. February 22-24, 2024. Gullickson, M., DiGiacomo, G., Rogers, M. \"Assessing spotted-wing drosophila organic control methods and economic viability in day-neutral strawberry production.\" Poster presented at Marbleseed Conference, La Crosse, WI. February 22-24, 2024. What do you plan to do during the next reporting period to accomplish the goals?Current plans include submitting 2peer-reviewed papers on the Effects of Mulches on Insect Pests in Organic Day-Neutral Strawberries and the Impact of Polyethylene and Paper Mulches on the Yield, Quality, and Development of Day-neutral strawberries in an Organic System in the Upper Midwest to HortTechnology. Completing an Extension factsheet for publishing online, and completing a foundational video on day-neutral strawberry production to be published online (https://extension.umn.edu/strawberry-farming/day-neutral-strawberries). Impacts What was accomplished under these goals? Objective 1. Fruit harvest of plots established in spring 2023 in an organic transitioning field at the West Madison Agricultural Station in Madison, WI and the St. Paul, MN, Experiment Station of the University of Minnesota was done on a biweekly interval from late July to late October 2023, after the first fall frost. Berries were graded at each harvest date into marketable berries following the guidelines for USDA grades #1 and #2, with the remainder being considered unmarketable. In 2023, unmarketable fruit was further subdivided into four groups: small fruit (\<10 g), tarnished plant bug damaged, diseased, and fruit which was damaged or otherwise unmarketable due to causes outside of the previous three causes (other), such as bronzing, thrips damage, wasp damage, and mechanical damage. Total fruit weight was recorded for marketable and all categories of unmarketable fruit after every harvest. In Wisconsin, individual berry weight was recorded once weekly by individually weighing 20 berries from each replicate. In Minnesota, individual berry weight was recorded once weekly by averaging the weight of 20 berries from each replicate. Fruit quality samples were collected only in the Wisconsin site on August 7, September 19, and October 5 in 2023. Samples were stored in a -80 ?C freezer and later analyzed for total soluble solids (TSS) and titratable acidity (TA). Postharvest quality was evaluated three times throughout the growing season in both Wisconsin and Minnesota, by selecting 15 marketable fruits from the harvest zone per treatment replicate (n= 60 berries per treatment), weighing them, and placing them in a 946 cm3 plastic clamshell container and storing them in a walk-in cooler at 4?C. Initial fruit weight was recorded before placing fruit in the cooler and every 5 days thereafter until 15 days post-harvest. Berries were also evaluated for the number of fruits with any visible fungal infection and/or emergent spotted wing drosophila (SWD) larvae by checking both the surface condition and for structural collapse of the fruit. At the final harvest in October 2023, plant biomass was collected by excavating four plants per treatment replication (n=16 plants per treatment) and separating them into roots, crowns, and leaves (including petioles). Biomass samples were dried in an oven at 60º C for 5 days or until constant weight, and dry weight was recorded for each subsample. Objective 2.Pollinator observations were conducted once weekly from 9/1/23 to 10/4/23. Five open flowers were observed for 10 minutes, during which any visitors were recorded and identified to species (e.g., Bombus, Apis) or morphogroup (all other insects). Flies from family Syrphidae were collected once weekly from 9/1/23 to 10/4/23 and assayed for exterior pollen loads by washing in ethanol, evaporative drying of the pollen, and subsequent rehydration with Calbera\'s Stain. Pollen counts were conducted on a haemocytometer of both strawberry pollen and other pollen. To monitor thrips populations, blue sticky cards were setup in Madison, WI on 5/18/23 and in St. Paul, MN in7/3/23in each plot and were changed every 2 weeks. During this reporting period, we identified all insect pest from sticky cards collected during the 2022 and 2023 growing season that have been kept in storage in a -20 C refrigerator. Objective 4. Two-year average enterprise analyses and partial budgets were completed for the different mulch systems under what was observed to be a low-pest pressure complex. An economic summary was drafted detailing the economic methods, results, and general conclusions. Results and conclusions:We found no significant difference in direct material costs by mulch treatment. Labor costs accounted for the majority of direct costs for all treatments on average over the two-year period in MN-WI. Modest differences in labor expenses and numerical yield between treatments resulted in observed differences in net returns between the control treatment 1 (white on black plastic mulch) and the other three mulch treatments. Day-neutral strawberries can break even on direct costs when yields average at least 0.5 pounds per plant and are priced at \$4.06/lb - \$4.68/lb, depending on mulch used. Treatment 3 (reflective mulch) was the most profitable mulch treatment (measured as returns over direct costs). Organic day-neutral strawberries, using any of the mulch treatments studied, represent a profitable opportunity for growers in the Midwest. Regardless of mulch used and yields observed, however, Midwest growers will need to market strawberries as a specialty product appealing to consumer preferences for locally grown and organic characteristics to justify price points well above supermarket berries distributed from cost competitive outstate production areas (e.g. California where the marginal cost of labor is significantly lower). Publications Type: Theses/Dissertations Status: Published Year Published: 2024 Citation: Miles-Kroening, J. (2024). Organic day-neutral strawberry production in the Upper Midwest: Impacts of film-based mulches on pollinator visitation and fruit yield (Masters thesis, University of Wisconsin-Madison). University of Wisconsin-Madison Library. Type: Conference Papers and Presentations Status: Published Year Published: 2024 Citation: Rogers, M., Miles-Kroening, J., Gullickson, M., Burkness, E., DiGiacomo, G., Guedot, C., Atucha, A., Holland, L. (2024). Effects of Mulch Type on Day-Neutral Strawberry Yield and Quality in an Organic Production System in the Upper Midwest. HortScience 59 (S9): 303. Type: Conference Papers and

Presentations Status: Published Year Published: 2024 Citation: Lannan, M. and Gu�dot C. (2024). Diversity and abundance of insects visiting grape and strawberry flowers in Wisconsin. HortScience 59 (S9): 154. Type: Other Status: Under Review Year Published: 2024 Citation: Miles-Kroening, J., Abbrescia, A., Workmaster, B.A., Atucha, A., Rogers, M., Holland, L., DiGiacomo, G., Guedot, C. (2024). Impact of Mulches on floral visitors in Day-Neutral Strawberries and Contribution of Syrphid Flies to Strawberry pollination. Journal of Applied Entomology. Submitted. Progress 09/01/22 to 08/31/23 Outputs Target Audience:Target audience is organic horticultural crop producers, new and existing strawberry producers, includes farmers from underrepresented audiences (Hmong producers). Changes/Problems:Material, labor, and other input data needed for the break-even analysis were provided by MN-WI field teams. Labor recorded by field teams for YR1 were compared with previous studies was found to be higher than anticipated, necessitating a re-evaluation of plot design, planting, plant maintenance, weeding and harvest protocols. Based on these preliminary findings, the field teams met in April 2023 to discuss and agreed on new protocols for YR2 of the study. Decisions were made to use a new seeding mix for the alleys between rows to reduce weeding labor, runner removal was standardized to 1 time per week, and marketable grades 1 & 2 would be combined since this is acceptable for local, organic markets. What opportunities for training and professional development has the project provided? Nothing Reported How have the results been disseminated to communities of interest?We published 16 news articles on insect and disease scouting for organic day-neutral strawberry production. These articles were published in the Wisconsin Fruit News that reaches over 800 subscribers. During 2023 we deliver a webinar through the Cold Climate Webinar Seriesorganized by UW-Madison, University of Minnesota, Iowa State University, and University of Illinois. Gullickson, M.G. and S. Slack. (2023) Day-neutral strawberries. High Tunnel Berry Production Webinar Series. University of Minnesota and University of Wisconsin Extension. URL:https://youtu.be/UNtyMG2KJKk During this reporting period we delivered six oral presentations to stakeholders in the Upper Midwest and the Great Plains, including one to theHmong American Growers Association. Gullickson, M.G. and S. Slack. (2023) Day-neutral strawberries. High Tunnel Berry Production Webinar Series. University of Minnesota and University of Wisconsin Extension. URL:https://youtu.be/UNtyMG2KJKk Gullickson, M. G. (2023) Day-neutral strawberries: Production and Pest Management. Hmong American Growers Association Annual Farmer Training. West Saint Paul, MN. Gullickson, M. G., and A. Klodd. (2023). Strawberry Production for the Beginning Grower. Minnesota Fruit and Vegetable Growers Association. St. Cloud, MN, January 19, 2023. Rogers, M. (2023) Organic Management Strategies for Insect Pests in Small Fruit. UMN Dept. of Horticultural Science Seminar. St. Paul, MN April 19, 2023. Rogers, M. and DiGiacomo, G. (2023) Strawberry fields forever: Organic strawberry production for Minnesota growers. Minnesota Dept. of Agriculture Organic Conference. St. Cloud, MN January 6, 2023, (\~30 people). Atucha, A. 2023.Organic day-neutral strawberry production. Great Plains Growers Conference. January 14, St. Joseph, MO. Miles-Kroening, J., Guedot, C., and Atucha, A (2023) \"Organic Day-Neutral Strawberry production in the Upper Midwest\" at the Wisconsin Fresh Fruit and Vegetable Annual Conference, held virtually on January 30, with 60 participants. The team hosted two field days, one at the West Madison Agricultural Research Station on August 31, 2023, with an attendance of about 25 growers, and a second field day at theUniversity of Minnesota Organic Field Day in St. Paul, MN on July 25, 2023,with an attendance of about 25 growers60 growers. For the field day hosted in Madison, WI we conducted a survey of attendees. Results from the survey showed that attendees gain knowledge on topics related to soil fertility, crop production, irrigation management, insect pest control, and disease scouting and management. Overall, attendees rated the field day excellent and reported that they would consider changing practices in their operation as a result of the information learned in the field day. The team developed two demonstration videos highlighting production practices including managing weeds (378 views) and mulch removal for organic day-neutral strawberry production (245 views). https://youtu.be/C4vZ9yz9c_k?si=Cp4vIjz9Lq0hdf_N https://youtu.be/ObCnhAOPm30?si=N9gpDIMjgpCTb36M During April 7 of 2023, we had our second meeting with our grower advisory board (first meeting took place November 18, 2021). During this meeting, the team members presented preliminary results for our first year of data (2022) and collected feedback from the board on how to improve our growing techniques. The board suggested to use a combination of organic rye grass and clover to plant in the alley way to reduce weed control labor, reduce the number of times runners are being tipped to once a week, and to change the source of organic fertilizer to a mix that has higher percentage of nitrogen. Overall, the grower advisory board was very enthusiastic about the project and was looking forward to the final report on this project. What do you plan to do during the next reporting period to accomplish the goals?Data from objectives 1, 2 & 3 will be analyzed, and a peer-reviewed publication will be prepared for the Journal of IPM and HortScience (or similar) reporting on yield, fruit quality, plant growth, and the response of insect pest and beneficial insect populations to mulches in an organic day neutral strawberry system in the Upper Midwest region. Complete economic analysis for YR 2 data and combine with YR1 to obtain 2-year average break-even estimates. Using pest and yield estimates, a sensitivity analysis will be completed to explore how changes in pest thresholds ultimately affect break-even and overall profitability for the different mulches studied.A peer-reviewed journal article is planned. We will deliver talks at grower conferences in Wisconsin and Minnesota, as well as a poster presentation at the Marbleseed organic conference. A webinar series on Organic Day-neutral strawberry production will be hosted by the team during the spring of 2024 as part of the Cold Climate Fruit Webinar Series organized by UW-Madison, University of Minnesota, Iowa State University, and University of Illinois. We will host another meeting with our grower advisory boards in the spring of 2024, with the objective of providing them an overview of all activities completed and preliminary results of data analysis. We will also seek feedback on best way to reach as many stakeholders as possible to share the results of our studies. Impacts What was accomplished under these goals? Objective 1: Determine plant growth, yield, and fruit quality of day-neutralstrawberries grown in four film-based mulches. In 2023, plots were established in an organic transitioning field at the West Madison Agricultural Station in Madison, WI and the St. Paul , MN, Experiment Station of the University of Minnesota. Plots consisted of raised beds covered with various film-based mulches. Beds were built and covered with mulches on 5/2/23 and 5/5/23 in Madison and St. Paul, respectively. Mulch treatments included white on black plastic, black plastic, reflective plastic, and heavy-duty crepe paper, each replicated 4 times. Irrigation installation was completed on 5/5/23 and 5/9/23 and alleys were seeded by hand with rye and clover on 5/18/23 and 5/12/23, in Madison and St. Paul, respectively. Cabrillo day-neutral strawberries were transplanted into the established beds on 5/8/23. Data loggers for tensiometers, soil temperature, air temperature, relative humidity, and light intensity were established on 6/15/23 and 5/17/23 in Madison and St. Paul, respectively, to monitor environmental conditions during the trial and to provide guidance for irrigation needs. Plant mortality was recorded on 5/15/23 and 5/22/23 in Madison and 5/24/23 in St. Paul, and dead plants were replanted.To assess mulch condition, percent visual coverage (PVC) and weed presence were recorded beginning on 6/5/23 and twice per month thereafter. Fertigation of plots began 5/22/23 and continued throughout the season on a weekly basis. Removal of flower clusters occurred from 5/31 to 6/29/23 and runner removal began on 6/21/23 and continued biweekly until 9/15/23. Maintenance of weeds in alleys and raised beds began on 5/31/23 and continued on a weekly basis with all equipment, labor, and materials being documented for economic analysis. Harvest began on 7/14/23 in St. Paul and 7/24/23 in Madison and occurred twice per week with weights, marketability, and insect damage ratings recorded for each harvest. Shelf-life evaluations were conducted on in St. Paul on 8/2 and 8/30/23 and a 3rd evaluation is scheduled for September, and in Madison on 8/7/23 with two more planned for September. The shelf-life evaluations were set up in a 4 ?C cooler and berry weights, fungal growth and insect injury were rated at approximately 0, 5, 10, and 15 days. Objective 2: Determine the impact of film-based mulches on insect pests and pollinators in strawberries. To monitor thrips populations, blue sticky cards were setup in Madison, WI on 5/18/23 and in St. Paul, MN in7/3/23in each plot and were changed every 2 weeks. Monitoring of tarnished plant bug was done using a handheld vacuum to sample 40-50 plants in each plot every 2 weeks from 7/12/23 to the end of the season in Madison and from5/30 to 8/1/23 in St. Paul. Pollinator samples were also collected using a handheld vacuum and flowers were sampled on plants in the entire row of each plot (50 row ft). Pollinator samples were collected every 2 weeks starting on 7/12/23. Sugar water floats of ripe strawberry fruit were used to sample spotted wing drosophila to detect larvae and began on 8/4/23 and was conducted every 2 weeks.In addition to the sugar water float method, egg counts will also be done on ripe fruit 3 times starting on 8/7/23. Pollinator observations were conducted once weekly from 7/12/23 to 10/4/23. Five open flowers were observed for 10 minutes, during which any visitors were recorded and identified to species (e.g., Bombus, Apis) or morphogroup (all other insects). Flies from family Syrphidae were collected once weekly from 7/24/23 to 10/4/23 and assayed for exterior pollen loads by washing in ethanol, evaporative drying of the pollen, and subsequent rehydration with Calbera\'s Stain. Pollen counts were conducted on a haemocytometer of both strawberry pollen and other pollen. Objective 3: Evaluate the pressure of insect pests and diseases in day-neutral strawberry systems from planting to harvest. Madison WI site: Scouting was conducted weekly from planting to harvest to assess for plant diseases and insect pests in the planting. Different methods were used to assess the presence of insects and diseases. Every week, 160 plants (40 plants per mulch treatment) were randomly selected and assessed for insect pest and disease presence and respective pressure using theUniversity of Wisconsin Extension BioIPM Strawberry Workbook. At each sampling point, two leaves or one flower cluster per plant were tapped into a white tray, and insects were counted. Mites were assessed on an incidence-basis: plants were evaluated for mite presence on older foliage and crowns. Each plant was also inspected for foliar disease symptoms. Declining or dead plants were removed and assessed in the laboratory for biotic causal agents. For spotted wing drosophila sampling, each row was assessed by lightly crushing ten fruits in a ziploc bag and adding a saltwater mixture (1 cup of salt per gallon of water) to cover the berries. After one hour, the water was drained into a coffee filter and all fruit fly larvae counted.Pyganic 1.4 II EC was applied at a rate of 50 fl oz. per acre via backpack sprayer 7 times over the course of the season on 7/17/23, 7/25/23, 7/31/23, 8/16/23, 8/21/23, 8/31/23, and 9/13/23 when it was determined that the mean incidence of Tarnished Plant Bug nymphs or adults across the field was greater than one TPB per 4 flower clusters. St. Paul MN site: A tank mix of insecticides and a fungicide was applied to all plots for tarnished plant bug management beginning on 6/22/23 and was repeated 5 times on a weekly basis for a total of 6 applications. Applications targeted adult and nymph tarnished plant bugs at the early stages of flower development to protect developing flower buds and subsequent fruit from feeding injury. The tank mix included the organic certified pesticides Pyganic 5.0 II, Debug Tres, and Oxidate 5.0. For each plot, 40 ft of row was sprayed, and 10 ft of row was left untreated as a check plot. Tarnished plant bugs were sampled weekly from plants using a handheld vacuum to obtain counts of adults and nymphs in the treated and untreated areas. Fruit was also harvested from each area, weighed, and rated for tarnished plant bug injury. Objective 4: Estimate the break-even prices and farm-level profitability for organic day-neutral strawberries under low and high pest pressure. Break-even estimates for day-neutral strawberry production using each of the four mulches was completed for YR1 in December 2022. Results were summarized in a one-page color hand-out for distribution at field days. Results were also included in a presentation for winter conferences and meetings. Publications Type: Other Status: Published Year Published: 2023 Citation: Gu�dot C. 2023. B Watch Out for Thrips Coming From Southerly Winds. Wisconsin Fruit News, Vol 8, Issue 3. May 19, 2023. Type: Other Status: Published Year Published: 2023 Citation: Abbrescia A, Gu�dot C, Holland L, Miles-Kroening J. Organic Day Neutral Strawberry Scouting Report for June 9, 2023. Wisconsin Fruit News, Vol 8, Issue 5. June 16, 2023. Type: Other Status: Published Year Published: 2023 Citation: Abbrescia A, Gu�dot C, Holland L, Miles-Kroening J. 2023. Organic Day Neutral Strawberry Scouting Report for June 15, 2023. Wisconsin Fruit News, Vol 8, Flash. June 22, 2023. Type: Other Status: Published Year Published: 2023 Citation: Abbrescia A, Gu�dot C, Holland L, Miles-Kroening J. 2023. Organic Day Neutral Strawberry Scouting Report for June 26, 2023. Wisconsin Fruit News, Vol 8, Issue 6. June 30, 2023. Type: Other Status: Published Year Published: 2023 Citation: Abbrescia A, Gu�dot C, Holland L, Miles-Kroening J. 2023. Organic Day Neutral Strawberry Scouting Report for June 30, 2023. Wisconsin Fruit News, Vol 8, Flash. July 12, 2023. Type: Other Status: Published Year Published: 2023 Citation: Abbrescia A, Gu�dot C, Holland L, Miles-Kroening J. 2023. Organic Day Neutral Strawberry Scouting Report for July 7, 2023. Wisconsin Fruit News, Vol 8, Issue 7. July 14, 2023. Type: Other Status: Published Year Published: 2023 Citation: Abbrescia A, Gu�dot C, Holland L, Miles-Kroening J. 2023. Organic Day Neutral Strawberry Scouting Report for July 14, 2023. Wisconsin Fruit News, Vol 8, Flash. July 20, 2023. Type: Other Status: Published Year Published: 2023 Citation: Abbrescia A, Gu�dot C, Holland L, Miles-Kroening J. 2023. Organic Day Neutral Strawberry Scouting Report for July 21, 2023. Wisconsin Fruit News, Vol 8, Issue 8. July 28, 2023. Type: Other Status: Published Year Published: 2023 Citation: Abbrescia A, Gu�dot C, Holland L, Miles-Kroening J. 2023. Organic Day Neutral Strawberry Scouting Report for August 4, 2023. Wisconsin Fruit News, Vol 8, Issue 9. August 11, 2023. Type: Other Status: Published Year Published: 2023 Citation: Abbrescia A, Gu�dot C, Holland L, Miles-Kroening J. 2023. Organic Day Neutral Strawberry Scouting Report for August 11, 2023. Wisconsin Fruit News, Vol 8, Flash. August 22, 2023. Type: Other Status: Published Year Published: 2023 Citation: Abbrescia A, Gu�dot C, Holland L, Miles-Kroening J. 2023. Organic Day Neutral Strawberry Scouting Report for August 18, 2023. Wisconsin Fruit News, Vol 8, Issue 10. August 25, 2023. Type: Other Status: Other Year Published: 2023 Citation: Gullickson, M.G. and S. Slack. (2023) Day-neutral strawberries. High Tunnel Berry Production Webinar Series. University of Minnesota and University of Wisconsin Extension. URL: https://youtu.be/UNtyMG2KJKk Type: Other Status: Other Year Published: 2023 Citation: Gullickson, M. G. (2023) Day-neutral strawberries: Production and Pest Management. Hmong American Growers Association Annual Farmer Training. West Saint Paul, MN. Type: Other Status: Other Year Published: 2023 Citation: Gullickson, M. G., and A. Klodd. (2023). Strawberry Production for the Beginning Grower. Minnesota Fruit and Vegetable Growers Association. St. Cloud, MN, January 19, 2023. Type: Other Status: Other Year Published: 2023 Citation: Rogers, M. (2023) Organic Management Strategies for Insect Pests in Small Fruit. UMN Dept. of Horticultural Science Seminar. St. Paul, MN April 19, 2023. Type: Other Status: Other Year Published: 2023 Citation: Rogers, M. and DiGiacomo, G. (2023) Strawberry fields forever: Organic strawberry production for Minnesota growers. Minnesota Dept. of Agriculture Organic Conference. St. Cloud, MN January 6, 2023. Type: Other Status: Other Year Published: 2023 Citation: Atucha, A. 2023. Organic day-neutral strawberry production. Great Plains Growers Conference. January 14, St. Joseph, MO. Type: Other Status: Other Year Published: 2023 Citation: Miles-Kroening, J., Guedot, C., and Atucha, A (2023) \"Organic Day-Neutral Strawberry production in the Upper Midwest\" at the Wisconsin Fresh Fruit and Vegetable Annual Conference, held virtually on January 30. Type: Other Status: Other Year Published: 2023 Citation: Atucha, A. Miles-Kroening, J., Holland, L., Guedot, C., and Abbrescia, A. (2023) \"Organic Day-Neutral Strawberry production\". Summer Field day West Madison Agricultural Research Station Verona, WI, on August 31, 2023. Type: Other Status: Other Year Published: 2023 Citation: Gullickson, M., DiGiacomo, G. (2023) Day-neutral Strawberry Field Trial Results: Preliminary Production and Pest Observations. University of Minnesota Organic Field Day. St. Paul, MN July 25, 2023. Progress 09/01/21 to 08/31/22 Outputs Target Audience:Target audience is organic horticultural crop producers, new and existing strawberry producers, includes farmers from underrepresented audiences (Hmong producers). Changes/Problems:In the St. Paul location, our first year of research included inclement weather including two notable hailstorms, however the plants recovered. The paper-based mulch in year 1 has shown severe degradation and based on our experience, is not suitable for the relatively long season of organic day-neutral strawberries. However, in the Madison location, the paper mulch treatment has withstood seasonal conditions very well. In addition, in the Madison location we observed heat stress damage to the plants in the early part of the summer, though the plants recovered fine. We have also experienced 89 plants dying due to an unidentified fungal disease (currently under culture for diagnosis). What opportunities for training and professional development has the project provided? Training and supervision provided to a visiting undergraduate REEU student from Red Lake Nation College, a public tribal land-grant community college on the Red Lake Indian Reservation in Red Lake, Minnesota. Professional development opportunity for graduate student and undergraduate summer intern attending the Wisconsin Berry Growers Association in 7/12/22 in Poynette WI. How have the results been disseminated to communities of interest? The project was highlighted at our Organic Specialty Crops Field Day at the University of Minnesota St. Paul campus, reaching 84 attendees (including farmers, master gardeners, agriculture-related business or non-profit representatives, and community members) on July 26, 2022. In evaluations, 88% of attendees reported they learned a lot or learned a good amount of new information. Results of the pests and disease scouting have been published online in the Wisconsin Fruit Newsletter which has a readership of over 400 commercial growers, master gardeners, and home growers. <https://fruit.wisc.edu/2022/07/28/organic-day-neutral-strawberry-production-field-update/>, <https://fruit.wisc.edu/2022/08/11/organic-day-neutral-strawberry-insects-and-diseases/>. <https://fruit.wisc.edu/2022/08/19/scouting-for-insects-in-day-neutral-organic-strawberries-2/>, What do you plan to do during the next reporting period to accomplish the goals? Continuation of field research in 2023 Completion of DNS enterprise analysis using first year results (DiGiacomo, Objective 4) Impacts What was accomplished under these goals? Objective 1:Determine plant growth, yield, and fruit quality of day-neutral strawberries grown in four film-based mulches. Raised beds covered with film-based mulches were established in an organic certified field (K2) on the St. Paul campus of the University of Minnesota from 5/9 - 5/10/22 and in an organic transition field (B605) at the West Madison Agricultural Research Station in Madison, WI in 5/16-5/19/22. Film based mulches included white on black plastic, black plastic, reflective plastic, and heavy-duty crepe paper mulch treatments, each replicated 4 times. Plots were planted with 'Cabrillo' day neutral strawberries on 5/11/22 and 5/20/22 in St. Paul and Madison locations, respectively. Hobo data recorders for air temperature, relative humidity, and light intensity were set up on 5/17/22 and 7/13/22 in St. Paul and Madison locations, respectively, with soil temperature recorders established on 5/27/22 and 5/25/22 in St. Paul and Madison locations, respectively, to monitor environmental conditions during the research trial. Tensiometers were set up on 5/20/22 and 5/25/22 in St. Paul and Madison locations, respectively, to monitor soil moisture to determine when irrigation is necessary. Plant mortality counts were taken on 5/20 and 6/1/22 and dead plants were replanted in St. Paul locations, and 5/23; 5/30, 6/6, and 6/13/22 in Madison. Mulch conditions (percent visual coverage) and weed cover were rated on 6/1/22 and subsequently twice per month in St. Paul and every other week starting 5/27/22 in Madison. Plants began flowering on 6/1/22 and fertigation of plots began 6/2/22 in St Paul, and 6/9/22 and 6/22/22 in Madison, respectively. Flower removal occurred from 6/6 - 6/17/22 and 6/9 to 6/27/22 in St. Paul and Madison, respectively. Runner removal began on 6/10/22 and is ongoing in St. Paul and 6/11/22 in Madison. Weeding and mowing of plots and alleys began 6/10/22 in St. Paul and Madison and continues on a weekly basis with all equipment, labor, and materials being documented and entered into spreadsheets for economic analysis. Harvest began on 7/22/22 in St. Paul and 7/28/22 in Madison and occurs twice per week with weights, marketability, and insect damage ratings recorded for each harvest. The first of three shelf-life evaluations were set up on 8/3/22 in St. Paul and 8/16/22 in Madison in a 4 degree C cooler and will be rated at approximately 0, 5, 10, and 15 days for fungal growth, insects, and weight with additional evaluations done monthly. The first of three fruit quality samples were collected on 8/8/22 for Brix, titratable acidity (TA), and anthocyanin content in Madison location. Objective 2:Determine the impact of film-based mulches on insect pests and pollinators in strawberries. Blue sticky cards for thrips were set up on 6/29 and 5/30/22 in St. Paul and Madison, respectively, in each plot and are changed every 2 weeks. Tarnished plant bug is sampled using a handheld vacuum to sample 25 plants in each plot every 2 weeks and started on 7/26 and 8/3/22 in St. Paul and Madison, respectively. Pollinator samples are taken using a handheld vacuum from the flowers on plants in the entire row of each plot, collected every 2 weeks, and started on 8/2 and 8/3 in St. Paul and Madison, respectively. Spotted wing drosophila was sampled using ripe fruit and a sugar water float to detect larvae on 8/5 and in 8/24/22 in St. Paul and Madison, respectively, and will be conducted every 2 weeks. To date insects observed in the plots besides thrips, tarnished plant bug, and spotted wing drosophila have included aphid spp., flea beetle, variegated cutworm, oblique banded leafroller. Two-spotted spider mites, Japanese beetle, European paper wasps, 7-spotted lady beetle adults and larvae, aphid mummies of parasitoid wasps, and green lacewing. Pollinator observations began 7/11/22 and continue biweekly at the Madison location. Objective 3: Evaluate the pressure of insect pests and diseases in day-neutral strawberry systems from planting to harvest. Disease scouting began shortly after planting 5/20/22 in Madison. Nine plants did not establish following planting and were rogued from the plot and assayed for fungal diseases; none were identified. Scouting for foliar diseases began in June 2022. Symptoms of Common Leaf Spot and Phomopsis leaf blight were observed in June, July, and August throughout the plot treatments. Common Leaf Spot numbers were stable throughout the summer months. Phomopsis leaf blight has declined throughout the summer months. No disease differences were observed between the mulch treatments. Fungicides were not applied as disease pressure was low in all treatments. Objective 4:Estimate the break-even prices and farm-level profitability for organic day-neutral strawberries under low and high pest pressure. Economic data collection spreadsheets designed and adapted for field studies (2.22). Review of preliminary labor, material, machinery input expenses and yield data compiled by field staff, Eric Burkness (6.22). Preliminary literature and collection of secondary data needed for enterprise analysis and break-even prices (7.22). Publications

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