

OREI Project Details

Award Year 2012

8 Research Projects

PROJECT INDEX

1. [Strategies to Improve Profitability of Organic Dairy Herds in the Upper Midwest](#) Grant No: 2012-51300-20015
2. [Targeted Grazing to Reduce Tillage: Environmental, Ecological, and Economic Assessment of Reintegrating Animal and Crop Production](#) Grant No: 2012-51300-20004
3. [Whole-farm Organic Management of Bmsb and Endemic Pentatomids Through Behaviorally-based Habitat Manipulation](#) Grant No: 2012-51300-20097
4. [Addressing Critical Pest Management Challenges in Organic Cucurbit Production](#) Grant No: 2012-51300-20006
5. [Creating an Organic Plant Breeding Center](#) Grant No: 2012-51300-20024
6. [Alternative Post-harvest Washing Solutions to Enhance the Microbial Safety and Quality of Organic Fresh Produce](#) Grant No: 2012-51300-20005
7. [Developing Adapted Varieties and Optimal Management Practices for Quinoa in Diverse Environments](#) Grant No: 2012-51300-20100
8. [Forage-based Parasite Control in Sheep and Goats in the Northeast U.s.](#) Grant No: 2012-51300-20320

Strategies to Improve Profitability of Organic Dairy Herds in the Upper Midwest

Accession No.	0230589
Subfile	CRIS
Project No.	MIN-16-G20
Agency	NIFA MIN
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2012-51300-20015
Proposal No.	2012-02201
Start Date	01 SEP 2012
Term Date	31 AUG 2016
Grant Amount	\$1,924,693
Grant Year	2012
Investigator(s)	Heins, B. J.; Endres, M. I.; Moon, R. D.; Sheaffer, C. C.; Sorge, U. S.; King, R. P.; Weyers, S. L.; Heleba, D. M.
Performing Institution	Animal Science, UNIV OF MINNESOTA, ST PAUL, MINNESOTA 55108

NON-TECHNICAL SUMMARY

Through a OREI funded planning grant our multidisciplinary team conducted focus group interviews, seminars, and organic dairy visits, and we concluded that organic dairy producers in the Upper Midwest seek to enhance forage production, increase milk production, and improve animal health to remain viable in the dairy industry. The present proposal addresses all three of these challenges through research involving the University of Minnesota's West Central Research and Outreach Center's certified organic dairy and cooperating organic dairy farms in the region. The overarching goal of our project is to enhance the profitability of organic dairy herds in the Upper Midwest through developing best management practices using a systems approach. We will develop methods to increase organic pasture productivity, improve cow health and well-being through winter housing and pasture fly management, and increase the profit of organic dairy herds through improved milk quality. Our stakeholder group of organic farmers helped identify and develop the objectives included in this proposal; and they will provide leadership for coordinated on-farm field research and sites for field days. The results of this project will be valuable to organic dairy producers, and will be disseminated to organic producers and industry representatives throughout the United States. Our research results will be shared with our larger stakeholder groups through field days, conferences, publications, and webinars. Use of eOrganic will allow stakeholders to review the progress of the work and discuss important issues related to organic agriculture with researchers and one another on a continuing basis.

OBJECTIVES

The overarching goal of our project is to enhance the profitability of organic dairy herds in the Upper Midwest by developing best management practices through a systems approach. We will develop methods to increase and extend organic pasture productivity, improve cow health and well-being through winter housing and pasture fly management, and increase the profit of organic dairy herds through reduced somatic cell count and reduced clinical mastitis. The results of this project will be valuable to organic dairy producers, and will be disseminated to organic dairy producers and industry representatives throughout the United States.

APPROACH

Data collected from the project will be analyzed using analysis of variance using the SAS system for statistical analysis. Models will be adjusted accordingly for each individual research study design. In some studies where the pen is replicated, pen will be used as the experimental unit rather than individual cow. Descriptive statistics will be used to characterize traits and performance for all research studies. Additionally, all animal performance data will be analyzed using the MIXED procedure of SAS with repeated measures. Treatment means will be separated using multiple comparisons tests. For some health performance and behavioral projects, data will be evaluated using non-parametric methods and logistic regression analysis. For the evaluation of mastitis prevention strategies, univariate analysis will be used to evaluate the association between a risk of new IMI and potential predictors. A Cox-Proportional Hazard model will be employed to compare the time to clinical mastitis within the first 100 DIM between the two drying-off strategies. Throughout the project and as the project nears its conclusion, we will solicit feedback from producers through the public workspace on eOrganic. The purpose of these conversations will be to reflect upon the research findings and outreach experiences and to suggest goals for the next phase of research in improving the profitability of organic dairy production systems. A key component of these conversations will be an evaluation of the knowledge gained in the project and changes in organic dairy practices. We will document changes in knowledge level using standard surveys through eOrganic and the University of Minnesota Extension program. Progress 09/01/12 to 08/31/17 Outputs Target Audience: We have reached organic dairy farmers and organic dairy industry representatives across the Upper Midwest region. We delivered a successful organic field day in August 2017 at the West Central Research and Outreach Center, Morris, MN that provided information on evaluating grazing pasture systems. Through this project we reached over 1,000 organic dairy farmers, and we have affected over 10,000 acres of organic pasture land through farmers incorporating warm season annuals and grazing management practices researched through this project. The field days were conducted for organic dairy producers, extension educators, organic industry and NRCS personnel. We educated 20 undergraduate college students through internships that focused on organic pasture management, fly control, and animal health at the WCROC. The project also educated and trained 8 graduate students with this project. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? The project has trained organic dairy producers on the use of summer annuals in a grazing system, control of mastitis on organic farms, and evaluated the profitability of overwintering and of grazing systems. Through the project over 1,500 extension educators and organic industry representatives were informed on organic dairy management practices at field days and conferences. We provided many education seminars to farmers, extension educators, and organic industry representatives. Five graduate students have completed Master's degrees during the project period. These degrees include the overwintering and fly control method objectives, and economics. We have trained 20+ undergraduate students on how to conduct research and outreach in an organic situation. How have the results been disseminated to communities of interest? Throughout the project period, we offered 6 organic dairy days at the University of Minnesota West Central Research and Outreach Center to provide farmers and other industry personnel tools for improving the profitability of organic dairy farms. Additionally, over 50 smaller tours and one-on-one tours with organic dairy producers were provided. We also had organic field days on cooperating organic farms that showcased rotational grazing systems, and over 250 people have attended the field days on cooperating organic farms. Over 2,000 people have attended presentations related to the objective research in the project. Over 975 views have been recorded on the eOrganic webinar that was conducted by Brad Heins on Grazing Systems and Forage Quality of Grasses for Organic Dairy Production on February 11, 2016. Over 1,400 views have been recorded on the eOrganic webinar that was conducted by Brad Heins and Roger Moon on Unique Fly Control Methods for Organic Dairy Production conducted on March 24, 2016. Over 500 views have been recorded on the eOrganic webinar that was conducted by Brad Heinson Considerations for Out-Wintering the Organic Dairy Herd conducted on November 21, 2014. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? Comparing Diverse Pasture Systems: The objective of this study was to compare warm season annual grasses to cool season perennial pasture for ruminal nutrient digestibility and nitrogen synthesis in a dual-flow continuous culture rumen fermentation system. Dietary treatments were: 1) alfalfa, 2) cool season perennial pasture (CSP), 3) brown midrib sorghum-sudangrass (BMRSS), and 4) teff grass from the organic dairy production system at the University of Minnesota organic dairy in Morris, MN. Treatments were randomly assigned to fermenters with 7 d of diet adaptation and 3 d of data and sample collection. Fermenter samples were collected on day 8, 9, and 10 for analysis of pH, NH₃-N, and VFAs. Apparent dry matter, organic matter, neutral detergent fiber, and acid detergent fiber digestibility were lower in pasture grasses (49.8%, 33.3%, 58.4%, and 60.8%, respectively) compared with alfalfa (69.4%, 54.1%, 75.5%, and 75.5%, respectively). True dry matter and organic matter digestibility were lower for pasture grasses (65.4% and 47.2%, respectively) compared with alfalfa (85.8% and 69.2%, respectively). Fermenter pH and total volatile fatty acids were not affected by forage. Ammonia N

concentrations were highest with alfalfa compared with the other pasture grasses. Crude protein degradation was not affected by forage treatment. Flow of NH₃-N was greatest for alfalfa, reflecting the greatest NH₃-N concentration. Flow of total N was greatest for alfalfa, lowest for CSP and BMRSS, and intermediate for teff. Flows of bacterial N, efficiency of bacterial N, non-NH₃-N, and dietary N were not affected by forage treatment. Overall, fermentation of warm season grasses was similar to the CSP, indicating the potential for successful use of warm season grasses in grazing systems for dairy cows. The PROC MIXED of SAS was used for statistical analysis, and independent variables were fixed effects of system (1; perennial or 2; perennial/annual), forage (perennial grass, BMRSS or teff) nested within system, year (2014 or 2015), system nested within year, and week nested within system, with replicate group nested within system as a random effect with repeated measures. System 1 and system 2 cows had similar milk production (14.7 and 14.8 kg/d), fat percentage (3.92% vs. 3.80%), protein percentage (3.21% vs. 3.17%), MUN (12.5 and 11.5 mg/dl), and SCS (4.05 and 4.07), respectively. For yearly effects, milk production was greater in 2015 compared to 2014 (15.6 vs 13.9 kg/d). The BW (485 and 497 kg) and BCS (3.10 and 3.06) were similar for system 1 and 2, respectively. Cows in system 1 had greater daily rumination (530 min/d) compared to cows in system 2 (470 min/d). In summary, warm season annual forage may be incorporated into grazing systems for organic dairy cattle while maintaining milk production and quality.

Outwintering economics: Certified-organic cows (n = 268), according to the USDA-National Organic Program rules, were used to evaluate the profitability of two winter housing systems (December to April). Cows were assigned to two treatments (two replicates per group): 1) outdoor (straw pack, n = 140) or 2) indoor (3-sided compost-bedded pack barn, n = 128). There were 21, 22, or 27 cows per replicate per year for the outdoor housing and 20, 21, or 22 cows per replicate per year for the indoor housing. Cows calved during two seasons (spring or fall) at the University of Minnesota West Central Research and Outreach Center, Morris, Minnesota, organic dairy. Organic wheat straw was used as bedding for the 2 outdoor bedded packs, which were 12 m wide by 27 m long. The straw packs were maintained by farm management to keep cows dry and absorb manure throughout the winter. The open-front compost-bedded pack barn (2 pens in the barn) was bedded with organic approved sawdust, and the bedding material was stirred twice per day with a small chisel plow. Cows were fed a TMR that included organic corn silage, alfalfa silage, corn, expelled soybean meal, vitamins and minerals. Daily feed consumption by each replicated group was monitored as the difference between feed offered and refused. Milk production was quantified with monthly DHI measures of milk, fat, protein, SCC, and milk urea nitrogen. Costs for key inputs and the price received for milk were monitored over the study period and averaged for use in the profitability analysis. The 'lsmmeans' package from the R software system was used for statistical analysis. Independent variables were fixed effects of year and housing system, with replicate as a random effect. Milk production, milk revenue, DMI, and feed cost were not different for the outdoor and indoor housing systems. Labor cost and bedding cost were significantly lower and net return was significantly higher for the outdoor housing system. In summary, the outdoor straw pack system has a \$1.42/cow/day net return advantage over indoor compost bedded pack barn system.

Effect of Drying-off Method on the Udder Health in Organic Dairy Farms: The use of antibiotics, including dry cow therapy, is prohibited in organic livestock production in the United States. Therefore, alternative management practices that maintain udder health need to be identified. The objective of this study was to compare the impact of abrupt or intermittent cessation of milking at dry-off on the cure of intramammary infections (IMI) throughout the dry period. Cows from one large organic dairy herd were assigned to either treatment by stratified randomization one week prior to dry-off. Cows assigned for intermittent milking were milked once daily for four days before dry-off, while cows assigned for abrupt milking were milked twice daily until dry-off. Aseptic quarter milk samples were collected at dry-off and at calving from all cows for subsequent bacteriological culture. A quarter was considered cured, when pathogen identified at dry-off could not be recovered from the same quarter at calving. A multilevel mixed logistic regression model that included cow as random effect was used to investigate the association between cure of IMI and dry-off method. A total of 159 cows (372 quarters) with IMI at dry-off and complete records were available for analysis. The prevalence of major and minor pathogens was 32% and 68% at dry-off, respectively. The mean of cumulative milk yield over the last four days of lactation was 31.5±2.2 kg and 18.8±1.4 kg for abrupt and intermittent cessation, respectively. While the dry-off method was not associated with the cure rate of IMI over the dry period, infection type at dry-off, parity, and SCC prior to dry off was associated with cure. Infections at dry-off caused by minor pathogens were more likely to cure (OR: 0.42, 95%CL: 0.24-0.70) compared to major pathogens. In conclusion, although intermittent milking reduced milk production during the last four days of lactation prior to dry-off, it had no effect on curing the probability of IMI during the dry period.

Publications Type: Journal Articles Status: Published Year Published: 2016 Citation: Sjostrom, L.S., B.J. Heins, M.I. Endres, R.D. Moon, and J.C. Paulson. 2016. Short communication: Relationship of activity and rumination to abundance of pest flies among organically certified cows fed 3 levels of concentrate. Journal of Dairy Science 99:99429948. doi:10.3168/jds.2016-11038. Type: Conference Papers and Presentations Status: Accepted Year Published: 2016 Citation: Activity and rumination in an organic vs. a conventional grazing herd. GM Pereira, BJ Heins, MI Endres. Journal of Animal Science 94, 618-619 Type: Conference Papers and Presentations Status: Accepted Year Published: 2016 Citation: Milk production, rumination, and body condition score of organic dairy cattle grazing two pasture systems incorporating warm and

cool season forages. KE Ruh, BJ Heins, J Paulson *Journal of Animal Science* 94, 316-316 Type: Conference Papers and Presentations Status: Accepted Year Published: 2016 Citation: Evaluation of five cool season grasses and alfalfa-grass mixtures. J Paulson, D Holen, D Nicolai, BJ Heins *Journal of Animal Science* 94, 686-686 Type: Conference Papers and Presentations Status: Accepted Year Published: 2017 Citation: Utilizing Forages for Dairy Production. Albert Lea Seed House Annual Open House. November, 17, 2017. Albert Lea Seed House. Albert Lea, Minnesota. Type: Conference Papers and Presentations Status: Accepted Year Published: 2016 Citation: Brad Heins and Kathryn Ruh. Forage Quality and Milk Production of Grazing Organic Dairy Cattle. In Proc. 2016 Penn State Dairy Cattle Nutrition Workshop. November 9-10, 2016. Grantville, PA. pg. 95-98 Type: Conference Papers and Presentations Status: Accepted Year Published: 2016 Citation: Brad Heins. Production, Economics, and Pest Management Strategies of Organic Grain Supplementation for Organic Dairy Cows. In Proc. 2016 Penn State Dairy Cattle Nutrition Workshop. November 9-10, 2016. Grantville, PA. pg. 113-120 Type: Conference Papers and Presentations Status: Accepted Year Published: 2016 Citation: Brad Heins. 2016. Effects of Flies on Dairy Cattle Welfare and Productivity. In Proc. Minnesota Nutrition Conference, Shakopee, MN. September 21-22, 2016. pp 107-108 Type: Conference Papers and Presentations Status: Accepted Year Published: 2016 Citation: 2016 Organic Dairy Research. NC-2042 Meeting. Fairlee, Vermont Type: Theses/Dissertations Status: Accepted Year Published: 2015 Citation: Sjostrom, Lucas. (2015). Alternative Housing and Management for Organic Dairy Production. Retrieved from the University of Minnesota Digital Conservancy, <http://hdl.handle.net/11299/178916>. Type: Theses/Dissertations Status: Accepted Year Published: 2016 Citation: Kienitz, Myrrh-Anna. (2016). Calf and Fly Management Options for Organic Dairies. Retrieved from the University of Minnesota Digital Conservancy, <http://hdl.handle.net/11299/181798>. Type: Theses/Dissertations Status: Accepted Year Published: 2017 Citation: Ruh, Kathryn. (2017). Comparison Of Two Different Grazing Systems Incorporating Cool And Warm Season Forages For Organic Dairy Cattle. Retrieved from the University of Minnesota Digital Conservancy, <http://hdl.handle.net/11299/185550>. Type: Other Status: Accepted Year Published: 2017 Citation: B. Heins. Effects of flies on dairy cattle welfare and productivity. *Progressive Dairyman*. <https://www.progressivedairy.com/topics/herd-health/effects-of-flies-on-dairy-cattle-welfare-and-productivity> Type: Conference Papers and Presentations Status: Accepted Year Published: 2017 Citation: Brad Heins. A NEW HORIZON: The Advancement of Organic Farming. Renaissance Nutrition Conference. January 24, 2017. Altoona, PA Type: Conference Papers and Presentations Status: Accepted Year Published: 2017 Citation: B. Heins. Alternative Management Strategies for Dairy Cattle Production. Minnesota DHIA Meeting. February 16, 2017. Detroit Lakes, MN Type: Conference Papers and Presentations Status: Accepted Year Published: 2017 Citation: K.E. Ruh, B. J. Heins, I.J. Salfer, R. Gardner, M.D. Stern. 2017. Dual-flow continuous culture fermentation of organic BMR sorghum-sudangrass and teff grass to determine digestibility of forages in an organic dairy grazing system. Abstract 77. 2017 ADSA Annual Meeting, Pittsburgh, PA Type: Journal Articles Status: Under Review Year Published: 2018 Citation: M. J. Kienitz, B. J. Heins, and R. D. Moon. 2018. Evaluation of a Commercial Vacuum Fly Trap for Controlling Flies on Organic Dairy Farms. *Journal of Dairy Science* Type: Journal Articles Status: Under Review Year Published: 2018 Citation: K.E. Ruh, B. J. Heins, I.J. Salfer, R. Gardner, M.D. Stern. 2018. Dual flow continuous culture fermentation of organic BMR sorghum-sudangrass and teff grass to determine digestibility of forages in an organic dairy grazing system. *Journal of Dairy Science* Type: Journal Articles Status: Under Review Year Published: 2018 Citation: Kienitz, M, B. J. Heins, and R. D. Moon. 2018. Evaluation of a Commercial Vacuum Fly Trap for Controlling Flies on Organic Dairy Farms. *J. Dairy Sci.* Type: Journal Articles Status: Accepted Year Published: 2017 Citation: Pereira, G.M., B.J. Heins, and M.I. Endres. 2017. Technical note: Validation of an ear-tag accelerometer sensor to determine rumination, eating, and activity behaviors of grazing dairy cattle. *Journal of Dairy Science*. doi:10.3168/jds.2016-12534. Progress 09/01/15 to 08/31/16 Outputs Target Audience: We have reached organic dairy farmers and organic dairy industry representatives across the Upper Midwest region. We have delivered an a successful organic field day at the West Central Research and Outreach Center, Morris, MN that provided information and a tour on evaluating grazing pasture systems, as well as discussing animal health alternatives with dairy producers. We were able to reach many new and beginning organic farmers through our workshops, field days, and conference presentations. The field days were conducted for organic dairy producers, extension educators, organic industry and NRCS personnel. We have also educated organic farmers at ten conferences about summer grazing systems and organic fly management. Furthermore, we are educating undergraduate college students through internships that focus on organic pasture management at the WCROC. We have also educated and trained graduate students with this project and two students successfully defended their Master's Thesis (one on fly control in our wintering systems and the other was evaluating fly control methods on organic dairy farms). Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? The project has trained organic dairy producers on the use of summer annuals in a grazing system, control of mastitis on organic farms, and with the CowVac, walk-thru fly trap. Many extension educators and organic industry representatives were informed on organic dairy management practices at field days and conferences. We provided many education seminars to farmers, extension educators, and organic industry representatives. Three graduate students have completed Master's degrees during the project period. These

degrees include the outwintering and fly control method objectives. We have trained 6 undergraduate students on how to conduct research and outreach in an organic situation. We also provided educational opportunities through two eOrganic webinars. How have the results been disseminated to communities of interest? We continue to offer an organic dairy day at the University of Minnesota West Central Research and Outreach Center to provide farmers and other industry personnel tools for improving the profitability of organic dairy farms. We also had organic field days on cooperating organic farms that showcased the CowVac. Over 75 people attended the field day at the University of Minnesota and over 250 people have attended the field days on cooperating organic farms. Over 1,000 people have attended presentations related to the objective research in the project. Over 275 views have been recorded on the eOrganic webinar that was conducted by Brad Heins on Grazing Systems and Forage Quality of Grasses for Organic Dairy Production on February 11, 2016. Over 400 views have been recorded on the eOrganic webinar that was conducted by Brad Heins and Roger Moon on Unique Fly Control Methods for Organic Dairy Production conducted on March 24, 2016. What do you plan to do during the next reporting period to accomplish the goals? The investigators on the project will meet this winter to review the objectives and accomplishments of the project. We will continue to work collaboratively to meet the project objectives. The analysis of data for the udder health objective will continue during the next year. We will continue to work on manuscripts for the study and submit them to appropriate peer reviewed journals. The last year of the project will focus on economic analysis of objectives and completion of udder health studies. Two master's degree students will defend their thesis on the summer annual grazing study and the economic analysis of outwintering and pasture systems. Information will continue to be disseminated at workshops, conferences, field days, and scientific conferences.

Impacts What was accomplished under these goals? Comparing Diverse Pasture Systems: For our study, ninety organic dairy cows were used in a study to compare two different pasture systems at the West Central Research and Outreach Center in Morris, MN. The first system (cool system) included a diverse mix of cool season perennial grasses and legumes such as perennial ryegrass, white clover, red clover, chicory, meadow bromegrass, orchardgrass, meadow fescue, and alfalfa. The second pasture system (warm system) was a combination of the cool season perennial mixtures and warm season annuals BMR sorghum sudangrass and teff grass. Perennial pastures were established in 2012. Warm season annuals BMR sorghum sudangrass and teff grass were planted in individual paddocks during the third week of May of each year. Forage samples were collected daily throughout the grazing seasons of 2013-2015. Dry matter was analyzed immediately after sample collection. Forage samples were tested at Rock River Labs in Watertown, WI for the forage quality characteristics neutral detergent fiber (NDF), total tract NDF digestibility (TTNDFD), crude protein (CP), and mineral content. Holstein and crossbred dairy cows were blocked by breed, parity, days in milk, and randomly assigned to one of two systems. Cows were moved to a new paddock every two days, were supplemented 5 lb. of corn per day, and provided with free-choice mineral in pasture. Milk production data was collected daily. Fat, protein, MUN, and SCC were from monthly DHI testing. Body weight was recorded on cows using a digital scale as cows exited the milking parlor approximately once every 2 weeks during lactations, and BCS was measured at the same time as BW on a 1 to 5 scale in increments of 0.25, with 1 = excessively thin, and 5 = excessively. Across the grazing season, spring pasture dry matter fluctuated across the grazing season and was higher during August and October compared to the early part of the grazing season (June and July). Seasonal average crude protein concentrations were greater for the perennial pastures in the fall; however, the warm season grasses were greater for crude protein during July at the time of first grazing. Forage quality was similar between cool season perennial pasture grasses and the warm season species evaluated in this study. Cool season pasture had higher average crude protein (23.0%) than the warm season grasses, but BMR sorghum sudangrass and teff grass still had adequate levels of protein for lactating cow diets (18.5 and 17.5%, respectively). Dry matter was higher in cool season pasture (23%) and teff grass (24%) than BMR sorghum sudangrass (20%). TTNDFD was similar between all types of forage. The mineral composition varied between the different grasses. There were no differences in milk production, components or quality between cows grazing only cool season pastures and cows in a system that incorporated warm season annuals. Average milk production was 32.3 lb for the cool system and 32.5 lb for the warm system. There was also no difference in body condition score, body weight, or activity between systems. Cows on cool season grasses did have higher daily rumination than cows in the warm season system. Cows in both systems follow similar trends in production including decreased production during times of high temperature and humidity. In 2015, cows in the warm system achieved higher production than cows in the cool system during July and August. In the first year of the study, cows in the cool season system needed to be supplemented with stored feed in a TMR due to a shortage of forage biomass in pasture, while cows in the system incorporating warm season grasses were still able to graze. The following year there were no difference between pasture systems. Fly Control Methods for Organic Dairies: The objective of this study was to evaluate the efficacy of a commercial vacuum fly trap (TRAP; CowVac, Spalding Laboratories, Reno, NV) in on-farm organic dairy production systems to control horn flies, stable flies, and face flies. This study was conducted at the University of Minnesota West Central Research and Outreach Center (WCROC) and 7 other organic dairy farms during the summer of 2015 in Minnesota. The study period was from June 4 to September 30, 2015. The organic dairy farms utilized in this study spanned from Southeast, to

Central, to Northwestern Minnesota, and ranged in herd size from 30 to 350 cows. The WCROC organic dairy herd had 130 milking cows. All herds had cows that were of numerous breeds of cattle and consisted of pure Holstein, pure Jersey and crossbreeds of Holstein and Jersey, and European dairy breeds. The 8 herds averaged in milk production from 7 to 23 kg per cow per day. Six herds milked cows in a milking parlor twice daily; however, 2 herds had a Lely Robotic Milking system (Lely, Maassluis, the Netherlands). The farms were divided into pairs by location in Minnesota and during the first period of the summer (June 4 to July 18) the TRAP was set up on one farm and during the second period of the summer (July 20 to September 30) the TRAP was sent to its paired farm. The time between July 18th and July 20th was the time the TRAP were moved to the other four farms. The two treatments were operated in a crossover design among farms and months (June, July, August, and September), such that each farm received both treatments (TRAP or no TRAP) within the summer. Farms were visited once per week to collect flies from the TRAP, as well as count and record horn flies, stable flies, and face flies on cows. Farms that did not have TRAPS were also visited to count and record fly numbers. Numbers of flies on cows in each herd were counted by trained observers once per week during the 2015 grazing season. Additionally, bulk tank production records (milk, fat percentage, protein percentage, and SCC), along with weekly cow numbers on farm were collected from each of the eight organic dairy farms. Daily milk production was calculated as total bulk tank production divided by the average cow numbers on farm. For analysis of data, fly numbers and milk production were averaged for each period (with or without TRAP) for each farm. Log transformations of fly counts were used as needed to satisfy analytical assumptions of equal variance and normal distribution in errors. Fly population growth rate was the slope of a linear line for the average individual weekly observation of fly numbers on cows for the period with and without the TRAP. The slope of the lines were analyzed for the horn fly, stable fly, and face fly and compared between the two periods. Horn fly numbers on cows were reduced by 44% on farm in the presence of a TRAP (11.4 vs. 20.5 flies/side) compared to the absence of a TRAP. Stable fly (5.4 vs. 7.1 fly/leg) and face fly (1.0 vs. 1.0 fly/cow) numbers were similar on farm whether the TRAP was present or absent on farms, respectively. Milk production was similar for farms with the TRAP (15.5 kg/d) compared to without (15.3 kg/d) the TRAP. Both bulk tank milk and milk components were statistically similar in the presence and absence of the TRAP, so benefits of the TRAP were too small to measure. The presence of a TRAP on farm reduced horn fly population growth rates (-1.01 vs. 1.00 flies/d) compared to the absence of a TRAP. Cows on farms with no housing (100% pasture) tended to have reduced horn fly numbers (11.7 vs. 28.3 flies/side) in the presence of a TRAP compared to the absence of a TRAP on farm. Cows on farms with housing had similar horn fly numbers (11.2 vs. 14.8 flies/side) in the presence of a TRAP compared to the absence of a TRAP on farm. In summary, these results indicate the TRAP was effective in reducing horn fly numbers on cows and reduced horn fly growth rates during the pasture season in organic dairy production systems but benefits in improved milk production were not evident. Publications Type: Journal Articles Status: Published Year Published: 2016 Citation: Sorge, U.S., R. Moon, L.J. Wolff, L. Michels, S. Schroth, D.F. Kelton, and B. Heins. 2016. Management practices on organic and conventional dairy herds in Minnesota. *Journal of Dairy Science*. 99:31833192. doi:10.3168/jds.2015-10193. Type: Journal Articles Status: Accepted Year Published: 2016 Citation: L. S. Sjostrom, B. J. Heins, M. I. Endres, R.D. Moon, and J. C. Paulson. 2016. Short communication: Relationship of activity and rumination to abundance of pest flies among organically certified cows fed three levels of concentrate. *Journal of Dairy Science*. Vol 99 Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: B.J. Heins. Organic Dairy Research. NC-2042 Meeting. Barcelona, Spain Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: B.J. Heins. Organic Dairy Research. Scientific Colloquium: Dairy Production. Barcelona, Spain. October 21, 2015 Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: B. J. Heins. Dairy Research West Central Research and Outreach Center. Presentation to Morris Kiwanis Club. November 2, 2015. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: B. J. Heins. Practical Information on Dairy Precision Technologies Real World Examples Uses and Shortcomings. 49th Annual North Dakota State Dairy Convention. Mandan, ND. November 3, 2015 Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Lachnicht-Wyers, S. and B. Heins. Productivity and Nutrient Cycling Comparisons of Perennial and Annual Forage Systems for Organic Dairy. Abstract 292-6. ASA, CSSA, and SSSA Annual Meetings, Minneapolis, MN November 2015. Type: Websites Status: Published Year Published: 2015 Citation: Heins, B. Are Organic Dairy Farms Profitable and Viable?. November, 2015. <http://www.extension.umn.edu/agriculture/dairy/organic/are-organic-farms-profitable-viable/> Type: Theses/Dissertations Status: Published Year Published: 2015 Citation: Hansen, Anna. (2015). Stable Flies, Winter Bedding, and Summer Dairy Cow Comfort. Retrieved from the University of Minnesota Digital Conservancy, <http://hdl.handle.net/11299/177039>. Type: Other Status: Published Year Published: 2016 Citation: Eorganic webinar. Grazing Systems and Forage Quality of Grasses for Organic Dairy Production. February 11, 2016. <http://articles.extension.org/pages/73357/grazing-systems-and-forage-quality-of-grasses-for-organic-dairy-production-webinar-by-eorganic> Type: Other Status: Published Year Published: 2016 Citation: Eorganic Webinar. Unique Fly Control Methods for Organic Dairy Production. March 24, 2016. <http://articles.extension.org/pages/73359/unique-fly-control-methods-for-organic-dairy-production-webinar-by->

eorganic Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: B. Heins, Forage quality of cover crops and other dairy grazing research from University of Minnesota. Grassworks Grazing Conference. January 2016 Type: Other Status: Published Year Published: 2016 Citation: Ruh, Kathryn and Brad Heins. 2016. Study looks at impact of warm season annual grasses for grazing organic dairy cows. Organic Broadcaster. May/June 2016. page9,16 Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: B.J. Heins. Organic pasture versus conventional dairying is there a difference in sustainability? Journal of Animal Science Suppl 2 94 (April 2016) Abstract 67 Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Myrrh-Anna Kienitz, Bradley Heins, Roger Moon. Evaluation of the CowVac for Controlling Flies on Minnesota Organic Dairy Farms MOSES Organic Conference Research Poster Session February 2016 Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Kathryn Ruh, Brad Heins, and James Paulson. Forage quality of two different pasture systems incorporating warm and cool season forages for grazing organic dairy cattle. MOSES Organic Conference Research Poster Session February 2016 Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Bradley. J. Heins, Glenda M. Pereira, Marcia I. Endres. 2016. Rumination sensors in an organic grazing system. Conference on Precision Dairy Farming. Leeuwarden, The Netherlands. June 2016 Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Brad Heins and Kathryn Ruh. 2016. Forage Quality of Two Different Pasture Systems Incorporating Warm and Cool Season Forages for Grazing Organic Dairy Cattle. In Proc. Four-State Dairy Nutrition and Management Workshop. Dubuque, IA June 2016 Page 55-59. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Kienitz, M and Brad Heins. Evaluation of the CowVac for controlling flies on Minnesota organic dairy farms. Abstract 1237 JAM 2016. Salt Lake City Utah. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Ruh, K., B. Heins, and J. Paulson. 2016. Forage quality of two different pasture systems incorporating warm and cool season forages for grazing organic dairy cattle. Abstract 634 JAM 2016. Salt Lake City Utah. Type: Other Status: Published Year Published: 2015 Citation: Heins, Brad. Considerations for Out-Wintering the Dairy Herd. WCROC News. November, 2015 Type: Theses/Dissertations Status: Published Year Published: 2016 Citation: Sjostrom, Lucas. (2015). Alternative Housing and Management for Organic Dairy Production. Retrieved from the University of Minnesota Digital Conservancy, <http://hdl.handle.net/11299/178916>. Type: Theses/Dissertations Status: Published Year Published: 2016 Citation: Kienitz, Myrrh-Anna. (2016). Calf and Fly Management Options for Organic Dairies. Retrieved from the University of Minnesota Digital Conservancy, <http://hdl.handle.net/11299/181798>. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Ruh, K., B. Heins, and J. Paulson. 2016. Milk production, rumination and body condition score of organic dairy cattle grazing two pasture systems incorporating warm and cool season forages. Abstract 661 JAM 2016. Salt Lake City Utah. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Pereira, G., B. Heins, M. Endres. 2016. Activity and rumination in an organic vs. a conventional grazing herd. Abstract 1282 JAM 2016. Salt Lake City Utah. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: A. Hansen. Production of stable flies (Stomoxys calcitrans) from straw bedding packs and sawdust compost barns, two alternative cold winter housing systems for dairy cows. Moses Organic Conference. February 2016. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: B. Heins. Organic Dairy Nutrition with Grazing. MOSES Organic Conference. February 2016 Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: B. Heins. Development, Challenges, and Practical Implications of Organic Dairy Systems. 2016 Oberweiss Dairy Meeting. February 23, 2016. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: B. Heins. Fly Control and its Effect on Milk Production. 2016 McIntosh Dairy Days. McIntosh, MN Progress 09/01/14 to 08/31/15 Outputs Target Audience: We have reached organic dairy farmers and organic dairy industry representatives across the Upper Midwest region. We have delivered an a successful organic field day at the West Central Research and Outreach Center, Morris, MN that provided information and a tour on evaluating cow health and mastitis, and comparing cows grazing 2 pasture systems. We also offered 2 field days at organic dairy farms participating in the research project. We showcase the CowVac and organic fly control methods on these farms. One farm also showcased the BMR sorghum-sudangrass grazing project and offered suggestions to others on grazing warm season grasses.? The field days were conducted for organic dairy producers, extension educators, organic industry and NRCS personnel. We have also educated organic farmers at fifteen conferences about summer grazing systems and organic fly management. Furthermore, we are educating undergraduate college students through internships that focus on organic pasture management and organic fly control at the WCROC. We have also educated and trained graduate students with this project and one successfully defended a thesis on the outwintering project. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? The project has trained organic dairy producers on the use of summer annuals in a grazing system and with the CowVac, walk-thru fly trap. Many extension educators and NRCS personnel were informed on organic dairy management practices at field days and conferences. We provided many education seminars to farmers, extension educators, and organic industry

representatives. We are training 3 graduate students and have trained 12 undergraduate students on how to conduct research and outreach in an organic situation. One graduate student has defended a masters thesis with the outwintering objectives of the project. We also provided educational opportunities through eOrganic with an outwintering webinar. How have the results been disseminated to communities of interest? We continue to offer an organic dairy day at the University of Minnesota to provide farmers and other industry personnel tools to for improving the profitability of organic dairy farms. Over 200 people have attended the field day. Over 1,000 people have attended presentations related to the objective research in the project. Over 250 views have been recorded on the eOrganic webinar that was conducted by Brad Heins on outwintering dairy cattle on November 20, 2014. What do you plan to do during the next reporting period to accomplish the goals? The investigators on the project will meet this winter to review the objectives and accomplishments of the project. We will continue to work collaboratively to meet the project objectives. The assessment of and data collection for the udder health objective will continue during the next year. The the walk-thru fly traps objectives will be completed and analysis will be conducted. Two master's degree students will defend their thesis on the CowVac study and summer annual grazing study. A student will be identified for the economic analysis for the outwintering objective. The udder health objectives will be continued and data collected will be completed. Information will continue to be disseminated at workshops, conferences, field days, and scientific conferences. Impacts What was accomplished under these goals? Outwintering: Certified-organic cows (n = 165), according to the USDA-National Organic Program rules, were used to evaluate the effect of two winter housing systems (December to April) on production, SCS, body weight, and BCS. Bedding cultures from the housing systems were also evaluated. Cows were assigned to two treatments (two replicates per group): 1) outdoor (straw pack, n = 81) or 2) indoor (3-sided compost-bedded pack barn, n = 84). There were 21 cows per replicate per year for the outdoor housing and 21 and 20 cows per replicate per year for the indoor housing. Cows calved during two seasons (spring or fall) at the University of Minnesota West Central Research and Outreach Center, Morris, Minnesota, organic dairy. Organic wheat straw was used as bedding for the 2 outdoor bedded packs, which were 12 m wide by 27 m long, and maintained by farm management to keep cows dry and absorb manure throughout the winter. The open-front compost-bedded pack barn (2 pens in the barn) was bedded with organic approved sawdust, and the bedding material was stirred twice per day with a small chisel plow. Cows were fed a TMR that included organic corn silage, alfalfa silage, corn, expelled soybean meal, vitamins and minerals. Milk, fat and protein production and SCS were recorded from monthly DHIA testing. Body weight and BCS were recorded bi-weekly as cows exited the milking parlor. The PROC MIXED of SAS was used for statistical analysis, and independent variables were fixed effects of year, season of calving, parity, housing system, with replicate and cow as a random effect. Energy-corrected milk and SCS was not different for the outdoor (15.3 kg/d, 2.88) and indoor (15.9 kg/d, 2.75) housing systems, respectively. In addition, outdoor and indoor housing systems were not different for body weight (537 vs. 542 kg) and BCS (3.25 vs. 3.28), respectively. Daily DMI was 18.8 kg/d for the outdoor cows and 19.1 kg/d for indoor cows. The total bacteria count tended to be lower in the outdoor (13.0 log₁₀ CFU/ml) compared to the indoor (14.9 log₁₀ CFU/ml) system. In summary, cows housed outdoors on straw-bedded packs did not differ from cows housed in an indoor compost-bedded pack barn for production and SCS, as well as body weight, BCS, or DMI. Certified-organic cows (n = 82) were used to evaluate the effect of two winter housing systems (December 2013 to April 2014) on hygiene scores, frostbite, teat condition, clinical mastitis, and activity and rumination. Cows were assigned to two treatments (two replicates per group): 1) outdoor (straw pack, n = 39) or 2) indoor (3-sided compost-bedded pack barn, n = 43). There were 20 and 19 cows per replicate for the outdoor housing and 22 and 21 cows per replicate for the indoor housing. Cows calved during two seasons (spring or fall) at the University of Minnesota West Central Research and Outreach Center, Morris, Minnesota, organic dairy. Organic wheat straw was used as bedding for the 2 outdoor bedded packs and were maintained by farm management to keep cows dry and absorb manure throughout the winter. The open-front compost-bedded pack barn (2 pens in the barn) was bedded with organic approved sawdust, and the bedding material was stirred twice per day with a small chisel plow. Hygiene scores were recorded bi-weekly as cows exited the milking parlor. Incidence of clinical mastitis was recorded in a binary manner as treated (1) or not treated (0) during a lactation. Frostbite incidence was collected monthly. Activity and rumination time (daily and 2-h periods) were monitored electronically using HR-LD Tags from SCR Dairy. Indoor cows had greater udder hygiene scores (1.7 vs. 1.5) and greater abdomen hygiene scores (1.9 vs. 1.6) compared with outdoor cows. Incidence of clinical mastitis was greater for indoor cows compared with outdoor cows (29.8% vs. 12.8%, respectively). Frostbite incidence was not different between indoor (34.3%) and outdoor (21.1%) cows. Daily rumination was 477 min/d for indoor cows and 508 min/d for the outdoor cows. In summary, cows housed outdoors on straw-bedded packs had cleaner udders and improved udder health compared with indoor cows. Comparing Diverse Pasture Systems: Two pasture systems (cool and warm season grass species) with enhanced in-field and landscape level species diversity were analyzed for forage quality characteristics across the grazing season at the West Central Outreach and Research Center organic dairy in Morris, MN for two years. System 1 was a diverse-mixture of cool season grasses and legumes (perennial ryegrass, white clover, red clover, chicory, orchardgrass, meadow brome grass, alfalfa, meadow fescue). System 2 was a combination of perennial polycultures and annual-warm season grasses (BMR

sorghum-sudangrass and teff grass). Grazing of lactating cows was initiated when forages were 20-30 cm tall and strip size was adjusted to leave 7-13 cm of refusals. Random samples of pasture forage were sampled every other day when a group of cows moved to a new paddock. Pasture clippings were randomly collected in a 0.76 m² square of pasture. Forage samples were sent to Rock River Laboratory, Inc., Watertown, WI and were analyzed with NIR spectrophotometry for DM, CP, and total tract NDF digestibility (TTNDFD). Data were analyzed using the MIXED procedure of SAS. Independent variables for analyses were the fixed effects of system (cool (1) or cool-warm (2)), month (May to October), forage (grass pasture, turnips, BMR sorghum-sudangrass or teff), year (2013 or 2014) and their interactions, and date of harvest was a random variable. The DM averaged 20.7% and 21.2% for systems 1 and 2, respectively (P=0.75). The CP was 21.2% and 18.3% for systems 1 and 2, respectively (P<0.05). The CP for system 1 averaged 19.9% in 2013 and 22.5% in 2014 (P<0.01). The CP for system 2 averaged 16.1% in 2013 and 20.4% in 2014 (P<0.01). The TTNDFD averaged 69.9% and 53.1% for system 1 and system 2, respectively (P<0.01). The TTNDFD was 78.1% in 2013 and 61.7% in 2014 for cool-season grasses, and 59.8% in 2013 and 46.4% in 2014 for warm season grasses (P<0.0001). In summary, CP and TTNDFD were greater in cool-season pasture systems; however, DM did not differ between pasture systems. Yearly effects and weather may affect forage quality in both pasture production systems.

Fly control methods: Stable flies, *Stomoxys calcitrans*(L.), are pests of dairy cows and other large livestock, developing as maggots in soiled bedding and other decaying organic material. We asked how debris from two different winter housing systems, outdoor straw bedding packs and covered sawdust compost barns, might compare as habitat for stable flies the following summer. Compared to compost bedding, we expected straw pile debris to be a better substrate, resulting in more and larger flies. In winters of 2013 and 2014, independently managed herds of 21-22 cows from the certified organic dairy herd at the University of Minnesota's West Central Research and Outreach Center in Morris were housed from November to May in replicated winter housing systems. After transfer to summer pasture, emergence traps were placed on debris piles to quantify stable fly emergence and fly size. Alsynite® sticky traps were placed adjacent to the piles to measure fly abundance, and flies were measured and dissected to assess size and female gonotrophic age. During peak emergence of both years, traps indicated straw piles produced significantly more flies (46-fold more in 2013) than compost piles ($p < 2.2e-16$). Adults from both sources were equal in size. Nearby sticky traps showed adults were equally abundant around both types of piles, and 57% of females captured at both types of piles were previtellogenic, indicating they emerged locally. Our results show that compost packs may help control fly numbers in summer, and straw piles present a serious fly production liability if not disposed of properly.

Publications Type: Journal Articles Status: Published Year Published: 2015 Citation: B. J. Heins and H. Chester-Jones. 2015. Effect of feeding kelp on growth and profitability of group-fed calves in an organic production system. *Professional Animal Scientist* 31:368-374 Type: Journal Articles Status: Published Year Published: 2015 Citation: Sorge, U.S., R.D. Moon, B. Stromberg, S. Schroth, L. Michels, L. Wolff, D. Kelton, and B. Heins. 2015. Parasites and parasite management practices of organic and conventional dairy herds in Minnesota. *J. Dairy Sci.* 98:3143-3151 Type: Journal Articles Status: Submitted Year Published: 2016 Citation: Sorge, U. S., Moon, R. D., Wolff, L., Michels, L., Schroth, S., Kelton, D., and B. Heins. 2015. Management Practices on Organic and Conventional Dairy Herds in Minnesota. *J. Dairy Sci.* 98: Type: Journal Articles Status: Submitted Year Published: 2016 Citation: Sjostrom, L. S, B. J. Heins, M. I. Endres, R.D. Moon, and J. C. Paulson. 2016. Short communication: Effect of organic grain supplementation on activity and rumination time and pasture fly activity of organic dairy cows. *J. Dairy Sci.* 99: Type: Journal Articles Status: Submitted Year Published: 2016 Citation: Sjostrom, L. S, B. J. Heins, M. I. Endres, R.D. Moon, and U. S. Sorge. 2016. Evaluation of winter housing systems for effects on hygiene, udder health, frostbite and rumination of organic dairy cows. *J. Dairy Sci.* 99: Type: Journal Articles Status: Submitted Year Published: 2016 Citation: Sjostrom, L. S, B. J. Heins, M. I. Endres, R.D. Moon, and U. S. Sorge. 2016. Evaluation of winter housing systems for effects on production, body weight, BCS, and bedding cultures of organic dairy cows. *J. Dairy Sci.* 99: Type: Theses/Dissertations Status: Accepted Year Published: 2015 Citation: Lucas Sjostrom. 2016. Alternative Housing and Management for Organic Dairy Production. University of Minnesota. Type: Other Status: Published Year Published: 2015 Citation: Heins, Brad. 2015. Organic Dairy Research News. University of Minnesota. June 2015. pp 1-4 Type: Other Status: Published Year Published: 2015 Citation: Heins, Brad. 2015. Plan your forage supply for summer grazing. <http://www.extension.umn.edu/agriculture/dairy/forages/plan-your-forage-supply-for-summer-grazing/index.html> April 11, 2015 Type: Other Status: Published Year Published: 2015 Citation: Heins, Brad. 2015. Rumination sensors in a grazing system. <http://www.extension.umn.edu/agriculture/dairy/precision-dairy/rumination-sensors-in-a-grazing-system/index.html> February 14, 2015 Type: Other Status: Published Year Published: 2015 Citation: Heins, Brad. 2015. Sorghum-Sudangrass and Teff as summer forages for livestock systems. <http://www.extension.umn.edu/agriculture/forages/variety-selection-and-genetics/sorghum-sudangrass-teff-summer-forage/> UMN Forage Quarterly, January, 2015 Type: Other Status: Published Year Published: 2014 Citation: Heins, Brad. 2014. Considerations for out-wintering the dairy herd. <http://www.extension.umn.edu/agriculture/dairy/facilities/considerations-for-out-wintering-the-dairy-herd/index.html> December 13, 2014 Type: Other Status: Published Year Published: 2015 Citation: Heins, B.

2015. Bridge seasonal changes in pasture quality. Hoards Dairyman. March 25, 2015. p. 215 Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Heins, B. J. 2014. Bridging the summer slump with warm season grasses and seasonal changes in forage quality of pastures. In: Proc. 75th Minnesota Nutrition Conference. Prior Lake, Minnesota, September 17-18, 2014, p. 178-179 Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Sorge, U. and B. Heins. 2015. Health and disease on organic dairy farms. OARS Symposium Conference Poster, LaCrosse, WI, February, 26 February 28, 2015. Type: Other Status: Published Year Published: 2015 Citation: Heins, B. J., A. R. Hazel, and L. B. Hansen. 2015. Fertility and production of 3-breed and third-generation Holstein-sired crossbreds compared with pure Holstein cows in a seasonal pasture production system. J. Dairy Sci. 98 (Suppl. 2). Abstract. 376 Type: Other Status: Published Year Published: 2015 Citation: Ruh, K. E., Heins, B. J., and J. C. Paulson. 2015. Forage quality of two different pasture systems incorporating warm and cool season forages for grazing organic dairy cattle. J. Dairy Sci. 98 (Suppl. 2). Abstract. M119 Type: Other Status: Published Year Published: 2015 Citation: Sjostrom, L. S., Heins, B. J., M. I. Endres, R. D. Moon, and U. S. Sorge. 2015. Evaluation of winter housing systems for effects on production, udder health, BCS, hygiene, frostbite, and rumination of organic dairy cows. J. Dairy Sci. 98 (Suppl. 2). Abstract. 695 Type: Other Status: Published Year Published: 2015 Citation: Hansen, A., R. Moon, B. Heins, M. Endres, C. Sheaffer, U. Sorge, R. King, and S. Weyers. 2014. Production of stable flies (*Stomoxys calcitrans*) from wheat straw bedding packs and sawdust compost barns, two alternative cold winter housing systems for dairy cows Entomological Society of America, 11-14, November, Portland, O

PROGRESS

2013/09 TO 2014/08 Target Audience: We have reached organic dairy farmers and organic dairy industry representatives across the Upper Midwest region. We have delivered an organic field day at the West Central Research and Outreach Center, Morris, MN that provided information and a tour on organic fly control methods, evaluating cow health and mastitis, and comparing cows grazing 2 pasture systems. The field day was conducted for organic dairy producers, extension educators, organic industry and NRCS personnel. We have also educated organic farmers at fifteen conferences about summer grazing systems and organic fly management. Furthermore, we are educating undergraduate college students through internships that focus on organic pasture management and organic fly control at the WCROC. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? The project has trained organic dairy producers on the use of summer annuals in a grazing system. We have also provided training opportunities with the walk-thru fly traps. Many extension educators were informed on organic dairy management practices at field days and conferences. We provided many education seminars to farmers, extension educators, and organic industry representatives. We are training 3 graduate students and have trained 8 undergraduate students on how to conduct research and outreach in an organic situation. How have the results been disseminated to communities of interest? We continue to offer an organic dairy day at the University of Minnesota to provide farmers and other industry personnel tools to for improving the profitability of organic dairy farms. Over 200 people have attended the field day. Over 1,000 people have attended presentations related to the objective research in the project. What do you plan to do during the next reporting period to accomplish the goals? The investigators on the project will meet this winter to review the objectives and accomplishments of the project. We will continue to work collaboratively to meet the project objectives. The assessment of and data collection for the udder health objective will continue during the next year. The the outwintering and walk-thru fly traps objectives will complete another year of data. We will move to on-farm experiments with grazing and fly control methods based on results of the first years of the project. The economic analysis will be in the later part of the year for the outwintering objective. Information will continue to be disseminated at workshops, conferences, field days, and scientific conferences.

2012/09 TO 2013/08 Target Audience: We have reached organic dairy farmers and organic dairy industry representatives across the Upper Midwest region. We have delivered an organic field day at the West Central Research and Outreach Center, Morris, MN that provided information and a tour on summer annual (BMR sorghum-sudangrass and teff grass) grazing to organic dairy producers, industry and NRCS personnel. We have also educated organic farmers at various conferences about summer grazing systems and organic fly management. A undergraduate student internship was provided for the summer to collect grazing and forage quality data for the grazing systems objective Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? The project has trained organic dairy producers on the use of summer annuals in a grazing system. We have also provided training opportunities with the walk-thru fly traps. We are also training 2 graduate students and 3 undergraduate students on how to conduct research and outreach. How have the results been disseminated to communities of interest? We initiated an organic dairy day at the University of Minnesota to provide farmers and other industry personnel tools to adapt summer annuals to their grazing system. Over 85 people attended the field day. Over 500 people have attended

presentations related to the objective research in the project. What do you plan to do during the next reporting period to accomplish the goals? The project team leaders and farmers have met and will continue to work together to accomplish the objective of the project. The assessment of udder health objective will begin during the next year, and the outwintering and walk-thru fly traps objectives will complete another year of data. Research grazing plots will be established on cooperating farms. Information will continue to be disseminated at workshops, conferences, field days, and scientific conferences.

IMPACT

2013/09 TO 2014/08 What was accomplished under these goals? Outwintering: Out-wintering continues to increase in popularity, and our stakeholders identified the economics of housing systems as an important research topic. In particular, they asked if out-wintered dairy cattle will stay healthy and comfortable. If so, out-wintering could reduce winter housing costs. We recently completed the first-two years of a three-year study to develop practical strategies for organic dairy producers to enhance the profitability of their farm by evaluating two winter housing systems and their effects on economics of organic dairy cows. Organic dairy cows at the University of Minnesota's West Central Research and Outreach Center, Morris, MN, that calved during fall and spring calving seasons were used to evaluate production, somatic cell score, dry matter intake, animal hygiene, and behavior of organic dairy cattle housed outdoors on a straw pack or indoors in a compost bedded pack barn. During the two years, 165 lactating Holstein and crossbred organic dairy cattle were assigned to a winter housing system (straw pack or compost-bedded pack barn). Organic wheat straw was used as bedding for the outdoor straw packs, which were 40 feet wide by 80 feet long, and maintained to keep cows dry and absorb manure throughout the winter. The open-front compost-bedded pack barn (2 pens in the barn) was bedded with sawdust, and the bedding material was stirred twice per day with a small chisel plow. Cows were fed a TMR that included organic corn silage, alfalfa silage, corn, expelled soybean meal, vitamins and minerals. The straw pack cows had similar milk, fat, and protein production than the compost bedded pack cows. Surprisingly, there were no differences in production between the two winter housing groups of organic cows for milk production or somatic cell score. The groups of cows also had similar dry matter intake, indicating that the cows that were housed on straw packs did not require more feed than cows housed in the compost bedded pack barn. However, cows consumed about 25% more dry matter intake during the winter of 2014 compared to the winter of 2013. The average temperature during the winter months was about 7 degrees colder during 2014 than 2013. Across the two winter seasons, there were no differences for body weight or body condition score for organic cows. For animal cleanliness, the cows housed on straw packs had udders that were cleaner than cows housed in compost bedded packs (udder hygiene score of 1.45 versus 1.73). We saw no difference in rumination time for cows housed outdoors or indoors. In future years, we will focus on the profitability of the two winter housing systems for organic dairy cattle. Economically, animals outdoors may require about 15 to 20% more feed for the season than animals kept in confinement housing, so improvements in animal health and welfare from out-wintering will need to exceed increased feed costs if out-wintering is to be a profitable option. There are several obvious benefits to out-wintering; building costs are lower, diseases associated with close confinement and poor ventilation are avoided, animals are generally cleaner, bedding costs could be reduced, feeding may be simplified, and herd size may be adjusted if weather conditions change quickly. There are five key messages to consider when considering outwintering, 1) provide adequate wind protection, 2) additional feed may be required for cows and heifers, 3) lactating cow teats should be dry before they leave the milking facility during cold weather, 4) health problems tend to be fewer than cows housed indoors or in confinement facilities, and 5) housing under the stars may not be for everyone

Comparing Diverse Pasture Systems: During the summer of 2013, we planted two summer annuals for grazing for the first time at the University of Minnesota WCROC dairy in Morris. BMR Sorghum-Sudangrass and Teff grass were planted to extend our forage supply. These grasses were seeded with a drill on May 28, 2013. BMR Sorghum-Sudangrass has increased in popularity due to the BMR gene and increased NDF digestibility (5-10% higher than regular sorghum-sudangrass). For seeding rate, we seeded BMR sorghum sudangrass in our fields and pastures at 20 lbs/acre. The cool-season species consist of mixtures of smooth brome grass, orchardgrass, red and white clover, and alfalfa. The dry matter of the sorghum-sudangrass was low because the cattle grazed the fresh forage in the early vegetative state. The summer annuals were not as high in crude protein as the cool-season grasses. However, with lower crude proteins, we probably improved nitrogen utilization of the milking herd. The ADF values of the grasses were very similar and are within the range of low 30's to mid-50's. All of these grass species were high in digestibility. The NDF levels were higher for the summer annual grasses compared to cool-season species. However, the total tract NDFD (TTNDFD) was lowest for the teff grass. TTNDFD is a measure of how much fiber is digestible, how fast the fiber digests, and how long a cow holds the fiber in the digestive system. The summer annuals were similar to the cool-season grasses for sugar and non-fiber carbohydrates, and they provided similar net energy for lactation and milk per ton as the cool

season grasses. Activity and rumination monitoring of cows on pasture: So far, we've gathered over 1,00,000+ data points. Activity and rumination is typically observed in two hour time blocks. In our dairy herd, activity and rumination patterns mirror each other; at night, the activity is low and rumination is high and vice versa during the day. Activity is at the highest in the evening (4:00-8:00pm), which is mainly because the cows are walking to and from the milking parlor. On average, our cows are ruminating 490 minutes per day, which is typical of most dairy cows. Beginning in May of 2014, our HR Tag readings showed high activity levels due to the cows moving out to pasture. Once the cows were moved closer to the milking parlor in June, activity levels decreased due to the cows close proximity to the parlor. On June 15, the cows moved to pastures farther from the barn, and thus activity increased again. Cows grazed sorghum-sudangrass for the first time on July 17, and the activity spiked remarkably. In the future, we will be evaluating other activity and rumination systems for cows, and hope to provide valuable information to dairy producers that install these activity and rumination monitoring systems. Fly control methods: Stable flies bite cattle and cause economic losses for organic dairy farmers. This study was designed to better understand stable fly production potential of different bedding materials and winter housing systems. Four herds of 21-22 cows were randomly assigned to one of two replicate outdoor straw bedding packs or one of two replicate indoor sawdust compost bedding pack barns. After cows were transferred to pasture May 28th, 2013, we sampled the remaining straw and compost packs with fly emergence traps to measure numbers of stable flies produced by the packs. Flies were emerging when we began sampling on June 14th, 2013.

Emergence rates peaked in late June, continued through July and declined to zero in August. Extrapolated totals indicated that approximately 1.5 million stable flies emerged from the average straw pack, as opposed to 27,000 from the average compost pack (a 98% reduction). These results show that stable fly prevention is a previously unrecognized benefit of compost barns for housing organic cattle in winter. In contrast, undisturbed straw bedding packs can produce enormous numbers of stable flies, beginning in spring and continuing into summer.

****PUBLICATIONS (not previously reported):**** 2013/09 TO 2014/08 1. Type: Journal Articles Status: Accepted Year Published: 2015 Citation: Sorge, U. S., Moon, R. D., Stromberg, B., Schroth, S., Michels, L., Wolff, L., Kelton, D., and B. Heins. 2015. Parasites and Parasite Management Practices of Organic and Conventional Dairy Herds in Minnesota. *J. Dairy Sci.* 97: (accepted) 2. Type: Journal Articles Status: Published Year Published: 2014 Citation: Buckley, F., N. Lopez-Villalobos, B. J. Heins. 2014. Crossbreeding: implications for dairy cow fertility and survival. *Animal*. 8:122-133 3. Type: Other Status: Published Year Published: 2014 Citation: 3. Heins, Brad. 2014. Crossbreeding ? implications for dairy cow fertility and survival <http://www.extension.umn.edu/agriculture/dairy/reproduction-and-genetics/crossbreeding-implications-for-dairy-cow-fertility-and-survival/> April 26, 2014 4. Type: Other Status: Published Year Published: 2014 Citation: 4. Heins, Brad. 2014. Plan now for summer forages and grazing. <http://www.extension.umn.edu/agriculture/dairy/organic/plan-now-for-summer-forages-and-grazing/> February 8, 2014 5. Type: Other Status: Published Year Published: 2014 Citation: Heins, Brad. 2013. Supplementation for the grazing cow. <http://www1.extension.umn.edu/agriculture/dairy/organic/supplementation-for-the-grazing-cow/index.html> December 7, 2013 6. Type: Other Status: Published Year Published: 2014 Citation: Heins, B. 2014. Crossbreeding in dairy cows. *International Federation of Organic Agriculture Movements Animal Husbandry Alliance Newsletter*, September 2014. Vol. 4. p.16 7. Type: Other Status: Published Year Published: 2014 Citation: Heins, B. 2014. Less organic grain equals more profit. *Hoard's Dairyman*. June 2014. p. 400 8. Type: Other Status: Published Year Published: 2014 Citation: Heins, Brad. 2014. Sorghum-Sudangrass and Teff as Summer Forages for Livestock Systems. *University of Minnesota, West Central News*, May 28, 2014 9. Type: Other Status: Published Year Published: 2014 Citation: Heins, Brad. 2014. Using Summer Annuals as Forages for Livestock Systems. *Midwest Forage Association Forage Focus*, March, 2014, p 10. 10. Type: Other Status: Published Year Published: 2014 Citation: Heins, Brad. 2014. Winter housing systems for organic dairy cows. 2014 *Morris SunTribune Farm Progress Supplement*, March 8, 2014 11. Type: Other Status: Published Year Published: 2014 Citation: Heins, Brad. 2014. Supplementation for the grazing cow. 2014 *Morris SunTribune Farm Progress Supplement*, March 8, 2014, pp 12. Type: Other Status: Published Year Published: 2014 Citation: Heins, Brad. 2014. Using summer annuals as forages for livestock systems. 2014 *Morris SunTribune Farm Progress Supplement*, March 8, 2014 13. Type: Other Status: Published Year Published: 2014 Citation: Heins, Brad. 2014. Winter housing systems for organic dairy cows. *University of Minnesota, West Central News*, February 19, 2014 14. Type: Other Status: Published Year Published: 2013 Citation: Heins, Brad. 2013. Supplementation strategies for organic dairy herds. *Graze*. October 1, 2013 15. Type: Other Status: Published Year Published: 2013 Citation: Heins, Brad. 2013. The cows are talking to us 24 hours a day! Are we listening? 2013. *University of Minnesota, West Central News*, September 4, 2013. 16. Type: Conference Papers and Presentations Status: Published Year Published: 2013 Citation: Heins, B. J. 2013. Organic dairy cattle management and nutrition. In: *Proc. 74th Minnesota Nutrition Conference*. Prior Lake, Minnesota, September 17-18, 2013, p. 178-179 17. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Heins, B., M. Endres, R. Moon, and J. Paulson 2014. Effect of organic grain supplementation on production, fatty acid profiles, and profitability of organic dairy cows. *MOSES Organic Conference Poster*, LaCrosse, WI, February, 27 ? March 1, 2014 18. Type: Conference Papers and Presentations Status: Published

Year Published: 2014 Citation: Hansen, A., R. Moon, B. Heins, M. Endres, C. Sheaffer, U. Sorge, R. King, and S. Weyers. 2014. Stable fly production from spring debris leftover from different organic dairy cow winter housing systems. MOSES Organic Conference Poster, LaCrosse, WI, February, 27 ? March 1, 2014. 19. Type: Other Status: Published Year Published: 2014 Citation: Heins, B. 2014. The cows talking to us 24 hours a day! Are we listening? Morris Sun Tribune. February 22, 2014. 20. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: R. Moon, B. Heins, M. Endres, and J. Paulson. 2014. Grain supplements for grazing organic cattle could increase face fly and horn fly populations. MOSES Organic Conference Poster, LaCrosse, WI, February, 27 ? March 1, 2014. 21. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Sjostrom, L. and B. Heins. 2014. Evaluation of different winter housing systems for effects of animal health and economics of organic dairy cows. MOSES Organic Conference Poster, LaCrosse, WI, February, 27 ? March 1, 2014. 22. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Paulson, J.C., B. J. Heins and D.G. Johnson. 2014. Seasonal changes in DM, CP, NDF, and NDF digestibility of pasture forage in dairy grazing production systems in Minnesota. J. Dairy Sci. 97 (E-Suppl. 1):159. Abstract 321. 23. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Sjostrom, L. S., B. J. Heins, M. I. Endres, R.D. Moon, J.C. Paulson. 2014. Effect of organic grain supplementation on activity and rumination time of organic dairy cows. J. Dairy Sci. 97 (E-Suppl. 1):281. Abstract 560. 24. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: 6. Sjostrom, L. S., B. J. Heins, M. I. Endres, R.D. Moon, U. S. Sorge. 2014. Effect of two winter housing systems on production, body weight, somatic cell count, BCS, and dry matter intake of organic dairy cows. J. Dairy Sci. 97 (E-Suppl. 1):295. Abstract 588 25. Type: Conference Papers and Presentations Status: Published Year Published: 2013 Citation: Moon, R. D., M. I. Endres, and B. J. Heins. 2013. Do grain supplements for grazing cattle affect face fly and horn fly populations? Entomological Society of America, 10-13, November, Austin, TX 26. Type: Conference Papers and Presentations Status: Other Year Published: 2014 Citation: Heins, B. Bridging the summer slump with warm season grasses and seasonal changes in forage quality of pasture. 2014 75th Minnesota Nutrition Conf., Prior Lake, MN 27. Type: Conference Papers and Presentations Status: Other Year Published: 2014 Citation: B. Heins, WCROC Organic Dairy Projects. 2014 WCROC Organic Dairy Day, Morris, MN, 8/12/2014 28. Type: Conference Papers and Presentations Status: Other Year Published: 2014 Citation: B. Heins. 2014. Transitioning an organic herd to be a grass milk herd Organic Valley Gen-O Regional Gathering, Goodhue, MN, 7/11/2014 29. Type: Conference Papers and Presentations Status: Other Year Published: 2014 Citation: B. Heins. 2014. Improving the nutritional value of organic milk Organic Valley Annual Meeting Workshop, LaCrosse, WI, 4/2/2014 30. Type: Conference Papers and Presentations Status: Other Year Published: 2014 Citation: B. Heins. 2014. Using summer annuals in dairy production systems McIntosh Dairy Day, McIntosh, MN, 3/20/2014 31. Type: Conference Papers and Presentations Status: Other Year Published: 2014 Citation: B. Heins. 2014. Crossbreeding dairy cattle for improved milk production on organic dairy farms. INPACQ Lait Biologique, Princeville, Quebec, Canada, 2/6/2014 32. Type: Conference Papers and Presentations Status: Other Year Published: 2014 Citation: B. Heins. 2014. The economic benefits of grain supplementation in a dairy production system. River Country RC & D Grazing Conference, Eau Claire, WI, 3/14/2014 33. Type: Conference Papers and Presentations Status: Other Year Published: 2014 Citation: B. Heins and K. Soder. 2014. Supplementation for the grazing cow: corn and alternatives. Grassworks Grazing Conference, Wausau, WI, 1/17/2014 34. Type: Conference Papers and Presentations Status: Other Year Published: 2013 Citation: B. Heins. 2013. Organic Dairy Cattle Nutrition and Management. 74th Minnesota Nutrition Conference, Prior Lake, MN, 9/18/2013

2012/09 TO 2013/08 What was accomplished under these goals? The winter housing systems project was initiated at the West Central Research and Outreach Center. We have collected daily milk production and cattle health treatments. We have collected bedding samples from the outdoor straw packs, as well as the sawdust bedding samples from the compost barn. Currently a graduate student is analyzing the first year data from the study, and a second year of the study will begin in December 2013. An Entomology graduate student has collected data of emerging stable flies from each the compost barn and straw packs across the summer of 2013. Thirty fly emergence traps were placed on the replicated winter housing systems, with 120 traps in total. Once per week all flies were collected and counted from the emergence traps. The data is currently being analyzed for daily catch rate of stable flies. During the summer of 2013, the walk-thru fly trap experiment was established at the West Central Research and Outreach Center. A latin square trial was established to test the Bruce walk-thru fly trap compared to the CowVac for capture rate of horn flies on organic dairy cattle. Four replicate groups of cows were moved through each trap on chosen test dates throughout the grazing season. On the test days, horn flies were netted from cows, subdivided into quarters, dusted with a fluorescent powder, and released back onto the four subsets of cows. Each group walk through the one trap or the other. Percent removal rate of horn flies for each trap will be calculated, and the study will be repeated during the summer of 2014. During May 2013, all organic grazing cattle were fitted with the SCR activity and rumination collar system. The system is establishing baseline activity and rumination for each individual cow, and data will be analyzed during December 2013 to

determine the how grazing affects activity and rumination behavior of cattle. An organic dairy day in August 2013 delivered education materials to organic dairy producers and industry representatives information about grazing summer annuals, horn fly management with walk-thru fly traps, and activity and rumination monitoring systems. ****PUBLICATIONS (not previously reported):**** 2012/09 TO 2013/08 1. Type: Conference Papers and Presentations Status: Published Year Published: 2013 Citation: 3. Heins, B. J. and J. C. Paulson. 2013. Estimating pasture forage mass for pasture-based dairy production systems with precision dairy technology. In: Proc. Precision Dairy Conference and Exp. Rochester, Minnesota, June 26-27, 2013, p. 139-140 2. Type: Other Status: Published Year Published: 2013 Citation: 3. Heins, Brad. 2013. Estimating pasture forage mass for pasture-based dairies. <http://www1.extension.umn.edu/agriculture/dairy/grazing-systems/estimating-past>

[↑ Return to Index](#)

Targeted Grazing to Reduce Tillage: Environmental, Ecological, and Economic Assessment of Reintegrating Animal and Crop Production

Accession No.	0230185
Subfile	CRIS
Project No.	MONB00365
Agency	NIFA MONB
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2012-51300-20004
Proposal No.	2012-02244
Start Date	01 SEP 2012
Term Date	31 AUG 2016
Grant Amount	\$1,499,815
Grant Year	2012
Investigator(s)	Menalled, F.; Carr, P.; Hatfield, P.; Miller, P.; Weaver, D.; Burrows, M.; Engle, R.; Bekkerman, A.; Boles, J.; Miller, Z.; Quinn, R.; Burkle, L.
Performing Institution	Land Resources & Environmental Sciences, MONTANA STATE UNIVERSITY, BOZEMAN, MONTANA 59717

NON-TECHNICAL SUMMARY

The Northern Great Plains is a leading producer of organic small grain, pulse, and oilseed crops; but management options are limited by highly variable precipitation and easily eroded soils. This area also has strong potential for low-input organic sheep production, but access to sources of grazing and feed represents a challenge for ranchers. Re-integrating livestock into diversified organic farming systems could enhance the economic and environmental sustainability of organic production in semiarid environments. Based on inputs from our advisory board, we have developed this regional research/extension/education project to evaluate integrated animal and crop production systems. This redesigned system replaces tillage with targeted sheep grazing to terminate legume cover crops, manage crop residues, and reduce weed, insect, and pathogen pressures. Advantages of the proposed system include reduced soil erosion, enhanced pest control, improved soil quality, enhanced nutrient cycling, and diversification of the economic base of the organic enterprise. This systems-level study combines on-farm research with information gathered in controlled experimental plots to increase our knowledge-base in the areas of crop production, animal health, holistic pest management, and economics. We will deliver our results through field days, news releases, technical bulletins, stakeholder and professional presentations, and web-based outlets. We will develop training opportunities and educational resources on sustainable organic agriculture for undergraduate and graduate students, and elementary and secondary rural schoolteachers. This information will help new and existing organic growers in semiarid regions balance economic and environmental constraints with sustainability goals. This project addresses four priorities defined NIFA-OREI for FY2012 and five legislatively-defined goals.

OBJECTIVES

Long term goal. Assess the joint production, economic, and environmental benefits of reducing tillage intensity by reintegrating livestock and crop production in semiarid environments. Research objectives 1. Compare the effects

of targeted sheep grazing versus mechanical tillage on soil nutrients, compaction, erosion, and water availability. 2. Compare crop yield and quality between targeted sheep grazed no-tillage organic systems and tillage-based organic systems. 3. Assess the top-down impacts of targeted sheep grazing on interactions between weeds, soil borne pathogens, insect pests, beneficial organisms, and crops. 4. Compare two lambing and two lamb finishing systems on lamb finishing performance, internal parasite infestations, carcass quality, and product shelf life. 5. Develop enterprise budgets to assess economic trade-offs and impacts of integrating organic sheep and crop production in semiarid environments. 6. Assess the relative importance of targeted grazing for ecosystem health, holistic pest management, lamb and crop production, and economic returns through an analytical computer-based model. Teaching and outreach objectives 7. Develop training opportunities and educational resources on sustainable organic practices for graduate students, undergraduate students, and rural schoolteachers. 8. Design and implement transformative outreach programs on integrated crop/livestock production systems that are economic and environmentally sustainable. Expected Outputs We will combine research and teaching activities performed at experimental plots with on-farm studies to conduct a regional assessment of the potential of targeted grazing to terminate cover crops and reduce tillage intensity in established organic systems with emphasis on biological system components including crops, pests, and beneficial organisms, as well their trophic interactions. To disseminate our results we will develop training opportunities and educational resources on sustainable organic agriculture for undergraduate and graduate students, and elementary and secondary rural schoolteachers. Specific events will include 1) professional development workshops for rural school teachers to prepare them to teach topics related to the project's research findings aligned with the science education benchmarks, 2) Field days and producers meetings, 3) News releases and technical bulletins, 4) Presentations at stakeholders and professional meetings, and 5) distance education material.

APPROACH

This research will be conducted at four locations in Montana and North Dakota, selected to represent a range of environmental conditions, management practices, and socio-economic contexts. At each site we will evaluate the impact of targeted sheep grazing as an approach to terminate cover crops on 1) soil nutrients, compaction, erosion, and water availability, 2) crop yield and quality, and 3) top-down impacts of targeted sheep grazing on interactions between weeds, soil borne pathogens, insect pests, beneficial organisms, and crops. At one of the experimental sites (Fort Ellis Experiment Station near Bozeman, MT) we will compare two lambing and two lamb finishing systems on lamb finishing performance, internal parasite infestations, carcass quality, and product shelf life. Specific metrics to be evaluated will include 1) Finishing performance, carcass characteristics, and tenderness evaluation, and 2) Carcass and meat data. To assess the economic sustainability of the proposed activities we will develop enterprise budgets to assess economic trade-offs and impacts of integrating organic sheep and crop production in semiarid environments. This analysis will include: 1) Input costs and revenues associated with current organic production including both observed and unobserved factors affecting costs and revenues, 2) Expected input costs and revenues associated with integrated organic production methods, and 3) Scenario analyses to identify economic conditions under which expected costs, revenues, and profitability of integrated organic production would provide economic sustainability and increased profits. A computer-based model analysis will be conducted to achieve a comprehensive understanding of how targeted grazing affects environmental quality, crop productivity, and economic outputs. To do so, we will evaluate the relationships among multiple ecological processes measured in the field experiments. Response variables will include: 1) Weed, pathogen and insect community abundance and composition; 2) Crop disease risk, 3) Abiotic soil attributes; 4) Grain yield and quality, 5) Production costs, and 6) Economic returns within each crop management system and phase, controlling for site-to-site and year-to-year variation. We will integrate the results of this research into our undergrad and graduate teaching programs. Specific activities will include: 1) Research experience for undergraduates, 2) Graduate and undergraduate teaching and 3) Face to face educational activities in small rural schools. Finally, we will Design and implement transformative outreach programs on integrated crop/livestock production systems that are economic and environmentally sustainable. The evaluation will adopt a systematic approach to assess the achievement of the research, educational, and outreach objectives. Data collected from monitoring and evaluation activities will be analyzed using qualitative and quantitative methods. Evaluation findings will be communicated to the leadership of the project in a timely and frequent manner (formative) and at the end of each year/cycle (summative). **Progress** 09/01/12 to 08/31/17 **Outputs** Target Audience: Our targeted audience included farmers, ranchers, other agricultural professionals, and extension agents with interest in dryland sustainable organic agriculture. We also targeted undergraduate and graduate students, and elementary and secondary rural schoolteachers interested in sustainable agriculture, animal production, and organic cropping systems. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Several undergraduate and graduate students, research technicians and post-doctoral associates collaborated in this project. Undergraduate students: Ali Thornton, Sam Leuthold, Andrew Thorson, Kyla Crisp, Lazaro Vinola, Marco Huot, Laura Ippolito, Genna Shaia,

Nathan Kerzner, Karl Owen, and Clare Dittermore. Graduated students: McKenzie, S.C. 2014. Toward ecologically-based management biodiversity and ecosystem functions in intensively managed agroecosystems. MS thesis. Montana State University. Johnson, S.P. 2015. Effects of organic and conventional cropping systems on plant diversity and plant soil feedbacks. MS thesis. Montana State University Westbrook, J. 2015. The effects of sheep grazing for *Pisum sativum* or *Melilotus officinalis* cover crop termination. MS thesis. Montana State University. Ranabhat, N. 2016. Effect of agronomic practices on disease management in Montana cropping systems. MS thesis. Montana State University. Adhikari, S. In Preparation (targeted defense: October 2017). Impacts of dryland farming systems on biodiversity, plant-insect interactions, and ecosystem services. Ph.D. dissertation. Montana State University Research Associates: Devon Ragen, Jeff Holmes Post Doctoral Research Associates: Zachariah Miller, Judit Barroso, Erik Lehnhoff, Timothy Seipel, and Suzanne Ishaq. How have the results been disseminated to communities of interest? Extension/outreach. Between 2013 and August 2017, results of this research were presented at 31 extension meetings in Montana, North Dakota, and South Dakota, directly reaching more than 2800 participants. At the international level, results were presented at the 2015 Ontario Fruit and Vegetable Convention (65 attendants) and the Aapresid Meeting in Argentina (400 attendants). Results were showcased in the eOrganic Webinar Innovative Approaches to Extension in Organic and Sustainable Agriculture on April 7, 2015 and the eOrganic Webinar Targeted Sheep Grazing in Organic Systems on October 11, 2016. As on August 23, 2017 these webinars were viewed 820 and 264 times, respectively. We produced the video MSU organic farming study finds diverse benefits (<https://www.youtube.com/watch?v=Y5w25UgWMTs>), with 1,751 views as August 23, 2017. As part of our program to train teacher in organic and sustainable agriculture, we produced the article Science in action: Biological and ecological principles of urban agriculture to be published in Designing urban agriculture programs to improve STEM learning and teaching. Patchen et al. eds. Springer and gave an invited presentation on this topic at the 2016 National Association Research in Science Teaching meeting. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported **Impacts** What was accomplished under these goals? 1\ Effects of grazing and tillage on soil quality Dickinson, ND Soil cores were collected between 2013-16 from the winter wheat/cover crop phase for the conventional till and grazed no-till systems, separated into four depths and analyzed for inorganic N (NO₃-N and NH₄-N). Soil N levels were affected by management system with spring NO₃-N higher in the conventional till system compared to the grazed no-till one. This was likely a result of the severe weed populations which may have depressed soil NO₃-N levels compared to the tilled system. Soil NH₄-N concentrations were not sensitive to management system. The high concentration of weeds effectively scavenges for soil available N, resulting in lower soil NO₃-N levels. Big Sandy, MT Soils cores (0-30 cm) were collected between 2014-2016 in the organic grazed and organic tilled plots, separated into three depths and analyzed for inorganic NO₃-N. During the three years, soil N concentrations were insensitive to management practices. 2\ Crop yield and quality. Dickinson Between 2013-16, wheat yield ranged from 2450 to 4650 kg/ha in tilled plots and was 60 to 90% lower in organic no-till plots, depending on the year ($P < 0.05$). Pea yield averaged from 850 to 3940 kg/ha in tilled plots and was 45 to 90% lower in no-till plots. Failure of cover crops to produce weed suppressive mulch, along with an inability of acetic acid applications and grazing to kill perennial and established annual weeds may have caused these results. Comparison of hand-weeded and non-weeded micro-plots indicated that differences in weed pressure explain much of the yield depression. Big Sandy In 2014, our farmer cooperator seeded winter wheat instead of spring cereal and it was not worth his time to adjust seed depth with respect to the six 40 x 40 ft grazed sweet clover plots, which resulted in wheat seed placement on the soil surface and near zero wheat establishment. Consequently, response crop yield results were not possible in 2015. Yield measurement of the 2015 grazed and tilled plots indicated observed no differences among systems. 3\ Impacts of targeted sheep grazing on associated biodiversity Dickinson Perennial weeds \Canada thistle (*Salsola kali*), field bindweed (*Convolvulus arvensis*), and dandelion (*Taraxacum officinale*) dominated the no-till systems, but were largely absent from tilled ones. Weed pressure increased over time with four no-till plots. Conversely, Canada thistle was essentially eliminated by 2016 in one of three OT plots with established populations at the beginning of the study. Carabid activity-density correlated with weed seed rain. Big Sandy Between 2013 and 2016, weed species richness and diversity did not differ between previously OG and OT plots. In both treatments, the two most abundant species observed in 2016 were field bindweed and Canada thistle. We also compared weeds, pollinator, carabid beetle communities, and bumblebee (*Bombus impatiens*) colonies between organic and conventional wheat fields between 2013-15. Despite a higher weed abundance and diversity in organic fields, bee communities did not differ between farming systems. Bee-flower networks in the organic system were larger and more complex containing a greater number of plant and bee taxa, compared to conventional systems, Bumblebee colonies relative growth rate and colony fitness were higher in organic than in conventional fields, probably due to the greater amount of pollen and nectar provided via weed diversity. We found no difference in disease incidence or severity between OT and OG plots on matured stage of spring wheat. Fort Ellis, MT A multivariate analysis indicated that carabid communities in winter wheat differed among systems in 2015 and 2016, but not in 2013 and 2014. However, carabid communities did not differ among systems during the cover crop phase. We are processing the 2017 data and will analyze the complete data set within the next six months.

4). Management of perennial weeds in organic systems. Corvallis, MT We evaluated which crops, crop sequences, and cultural methods more effectively suppress field bindweed. In 2015, rhizome were planted in 1m² plots at 0, 4, 12, and 32 fragments plot-1 and ten cropping treatments were imposed. In the fall of 2016, all plots were planted to winter wheat. In spring 2017, bindweed abundance and spread was measured. Winter wheat and was safflower halted increases in patch growth and fruit production. Tilled fallow management led to a 10x increase in the number of bindweed shoots over the growing season. Meta-analysis We conducted meta-analyses of the existing literature to 1) identify promising management approaches for field bindweed and Canada thistle in the absence of synthetic herbicides and 2) determine which aspects of management warrant further study. Mechanical control was the most studied management technique, accounting for 40% of data extracted, but did not outperform most of the other management actions. Integrated management, or the combination of two or more control methods, emerged as the management technique that caused the greatest decrease in abundance and survival for field bindweed. We identified additional management techniques that decreased field bindweed and/or Canada thistle including biocontrol, mowing, grazing, crop diversification, solarization, shading, flaming, and crop competition. However, most of the studies we evaluated reported impacts over short time spans, with 53% being conducted for a period of one to two years, and only 9% conducted for five or more years. Further, only 16% of field bindweed and 26% of Canada thistle studies reported measures of variability.

5). Lambing and finishing systems on finishing performance, health, quality, and product shelf life We compared lamb growth and carcass characteristics under four management systems during the first two years of this project: 1) high energy - 60% barley, 2) moderate energy - 70% alfalfa, 3) continuous graze, and 4) rotational graze. Body weight and rib eye area did not differ between barley and alfalfa diets but it was lower in both grazing treatments.

6). Enterprise budgets of integrating organic sheep and crop production in semiarid environments. We developed a cost of production budget for three representative systems (conventional no-till, organic tilled, and organic grazed) and two scenarios (transitional period and certified period). Our analysis contemplated net returns under many possible economic environments based on historical data of input costs, market prices, and yield variability. During transitional period, five-year returns for the conventional, tilled, and grazed systems were \$723/acre, \$741/acre, \$414/acre respectively. During certified period, five-year returns for the conventional, tilled, and grazed systems were \$901/acre, \$2,979/acre, \$1,382/acre, respectively. Results suggest that if yields in grazed systems cannot be improved, then either increases in grazing services or payments for soil conservation would be needed.

7). Training opportunities and educational resources on sustainable organic practices SFBS 296. Summer Practicum Course. Undergraduate course discussed approaches to the sustainable integration of sheep grazing into vegetable production. ENSC410/LRES 510. Biodiversity Survey and Monitoring. This undergraduate course utilized the Ft. Ellis field site to assess the impact of management systems on biodiversity. MSU AGSC 428/ LRES 529 Sustainable Cropping Systems.. Topic included ecologically based weed management and integrated crop - livestock systems. ANRN 222. Livestock in Sustainable Systems. This course revised concepts of sustainable livestock production. MSU LRES 110. Introduction to Land Resources and Environmental Sciences. Guests lectures on ecologically based weed management and integrated crop - livestock systems in organic fields. Also, students visited the Ft. Ellis Research Farm. Weed Biology and Ecology, PLSC 433/633, NDSU. ****Publications**** - Type: Journal Articles Status: Under Review Year Published: 2018 Citation: McKenzie, S, H. Parkinson, M. Burrows, S. Ahmed, and F. Menalled. In Review. Perceptions, experiences, and priorities supporting agro-ecosystem management decisions differ among agricultural producers, consultants, and researchers. Submitted to Renewable Agriculture and Food Systems. - Type: Journal Articles Status: Under Review Year Published: 2018 Citation: Adhikari, S., T. Seipel, F. D. Menalled, and D. K. Weaver. In Review. Agricultural management system and wheat cultivar affect infestation and parasitism on wheat stem sawfly (*Cephus cinctus* Norton) in the Northern Great Plains. Submitted to Pest Management Science. - Type: Journal Articles Status: Under Review Year Published: 2018 Citation: Ranabhat, N., T. Seipel, E. Lenhoff, Z. Miller, K. Owen, F. Menalled and M. Burrows. Accepted with minor revisions. Temperature and alternative hosts influence *Aceria tosichella* infestation and Wheat streak mosaic virus infection. Plant Disease - Type: Journal Articles Status: Accepted Year Published: 2018 Citation: Orloff, N., J. Mangold, Z. Miller, and F. Menalled. Accepted with minor revisions. A meta-analysis of field bindweed (*Convolvulus arvensis* L.) and Canada thistle (*Cirsium arvense* L.) management in organic agricultural systems. Agriculture, Ecosystems and Environment. - Type: Journal Articles Status: Published Year Published: 2017 Citation: Carr, P.M. 2017. Guest editorial: conservation tillage for organic farming. Online. Agriculture 7(3), 21; doi:10.3390/agriculture7030021 - Type: Journal Articles Status: Published Year Published: 2017 Citation: Bhowmik, A., A. Fortuna, L.J. Cihacek, A.I. Bary, P.M. Carr, and C.G. Cogger. 2017. Potential carbon sequestration and nitrogen cycling in long term organic management systems. Renewable Agriculture and Food Systems <https://doi.org/10.1017/S1742170516000429> - Type: Journal Articles Status: Published Year Published: 2017 Citation: Ishaq, S., S. Johnson, Z. Miller, E. Lehnhoff, S. Olivo, C. Yeoman, and F. Menalled. 2017. Impact of cropping systems, soil inoculum, and plant species identity on soil bacterial community structure. Microbial Ecology 73:417-434. - Type: Journal Articles Status: Published Year Published: 2017 Citation: Johnson, S., Z. Miller, P. Miller, E. Lehnhoff, and F. Menalled. 2017. Cropping systems modify soil biota effects on wheat

(*Triticum aestivum* L.) growth and competitive ability. *Weed Research* 57: 6-15. - Type: Journal Articles Status: Published Year Published: 2017 Citation: Lehnhoff, E., Z. Miller, P. Miller, S. Johnson, T. Scott, P. Hatfield, and F. Menalled. 2017. Organic agriculture and the quest for the holy grail in water-limited ecosystems: Managing weeds and reducing tillage intensity. *Agriculture* 7, 33; doi:10.3390/agriculture7040033. - Type: Journal Articles Status: Published Year Published: 2016 Citation: Nix, E.E., D.L. Ragen, J.G.P. Bowman, R.W. Kott, M.K. Petersen, and P.G. Hatfield E. Glunk. 2016. Forage intake and wastage by ewes in pea/hay barley swath grazing and bale feeding systems. *American Journal of Experimental Agriculture* 12 (3) 1-6 - Type: Journal Articles Status: Published Year Published: 2015 Citation: Goosey, H.B, S. C. McKenzie, M. G. Rolson, K. M. O'Neill, and F. Menalled. 2015. Impacts of contrasting alfalfa (*Medicago sativa*) production systems on the drivers of carabid beetle (Coleoptera: Carabidae) community dynamics. *Environmental Entomology* 44:1052-1064. - Type: Journal Articles Status: Published Year Published: 2016 Citation: Ragen, D. L., E. E. Nix, W. A. Whitehurst, T. M. Novell, R. B. Sager, E. S. Read, B. S. Hauptman, C. G. Hooley, and P. G. Hatfield. 2016. Effects of swath grazing pea-barley forage, bale-fed pea-barley forage, and straw stubble grazing on ewe body weight and number of lambs born. *American Journal of Experimental Agriculture* 11(2): 1-10. - Type: Journal Articles Status: Published Year Published: 2016 Citation: McKenzie, S., H. Goosey, K. M. O'Neill, and F. Menalled. 2016. Integration of sheep grazing for cover crop termination into market gardens: Agronomic consequences of an ecologically-based management strategy. *Renewable Agriculture and Food Systems* 1-14 doi:10.1017/S1742170516000326 - Type: Journal Articles Status: Published Year Published: 2016 Citation: McKenzie, S., H. Goosey, K. M. O'Neill, and F. Menalled. 2016. Impact of integrated sheep grazing for cover crop termination on weed and ground beetle (Coleoptera:Carabidae) communities. *Agriculture, Ecosystems and Environment* 218: 141-149. - Type: Journal Articles Status: Published Year Published: 2016 Citation: Barroso, J., Z. Miller, E. Lehnhoff, P. Hatfield, and F. Menalled. 2016. Impacts of cropping system and management practices on the assembly of weed communities. *Weed Research* 55:426-435. - Type: Journal Articles Status: Published Year Published: 2016 Citation: Barsotti, J.L., Sainju, U.M., Lenssen, A.W, Miller, Z.J. and Hatfield, P.G. 2016. Sheep grazing enhances coarse relative to microbial organic carbon in dryland cropping systems. *Sustainable Agricultural Research*. 5:1-14. doi: 10.5539/sar.v5n2p1. - Type: Journal Articles Status: Published Year Published: 2015 Citation: Miller, Z. and F. Menalled. 2015. Impact of species identity and phylogenetic relatedness on biologically-mediated plant-soil feedbacks in a low and a high intensity agroecosystem. *Plant and Soil* 389: 171-183. - Type: Journal Articles Status: Published Year Published: 2015 Citation: Miller, Z.; F. Menalled, U.M. Sainju, A.W. Lenssen, and P.G. Hatfield. 2015. Integrating sheep grazing into cereal-based crop rotations: Spring wheat yields and weed communities. *Agronomy Journal* 107: 104-112 - Type: Theses/Dissertations Status: Published Year Published: 2014 Citation: McKenzie, S.C. 2014. Toward ecologically-based management biodiversity and ecosystem functions in intensively managed agroecosystems. MS thesis. Montana State University - Type: Book Chapters Status: Awaiting Publication Year Published: 2018 Citation: Grimberg, B. and F. Menalled. In Press. Science in action: Biological and ecological principles of urban agriculture. In *Designing urban agriculture programs to improve STEM learning and teaching*. Patchen, A. Barnett, M. Esthers, L., and Knobloch, N., eds. Springer - Type: Theses/Dissertations Status: Published Year Published: 2015 Citation: Johnson, S.P. 2015. Effects of organic and conventional cropping systems on plant diversity and plant soil feedbacks. MS thesis. Montana State University - Type: Theses/Dissertations Status: Published Year Published: 2015 Citation: Westbrook, J. 2015. The effects of sheep grazing for *Pisum sativum* or *Melilotus officinalis* cover crop termination. MS thesis. Montana State University - Type: Theses/Dissertations Status: Published Year Published: 2016 Citation: Ranabhat, N. 2016. Effect of agronomic practices on disease management in Montana cropping systems. MS thesis. Montana State University - Type: Theses/Dissertations Status: Other Year Published: 2017 Citation: Adhikari, S. In Preparation (targeted defense: October 2017). Impacts of dryland farming systems on biodiversity, plant-insect interactions, and ecosystem services. Ph.D. dissertation. Montana State University - Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Menalled F., S. Adhikari, L. Burkle, K. O'Neill, and D. Weaver. 2016. Impact of cropping systems on bee community and colony fitness in water-limited agroecosystems. XXV International Congress of Entomology. September 25-30, 2016. Orlando, FL. - Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Briar, S.S., P.M. Carr, G.G. Gramig, F. Menalled, and P.R. Miller. 2016. Current status and soil biology impacts of organic conservation tillage in the U.S. Great Plains. International seminar on emerging trends in organic farming and sustainable agriculture. December 29-31, 2016. Mahatma Gandhi University. Kottayam, India. - Type: Conference Papers and Presentations Status: Other Year Published: 2014 Citation: Menalled, F. 2014. Iowa State University. Department of Agronomy. Invited presentation: Diversity across the landscape. Implications for Iowa cropping systems - Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Menalled, F., S. McKenzie, H. Goosey, K. O'Neill, S. Adhikari, and N. Ranabhat. 2015. Integrating targeted grazing in organic systems: Impacts on weed and ground beetle communities. 2015 American Society of Agronomy Annual Meeting. Symposium--Management and Biological Control of Weeds in Agroecosystems. Nov. 16-18, 2015. Minneapolis, MS. - Type: Conference Papers and Presentations Status: Other Year Published: 2014 Citation: Menalled, F. 2014. USDA-NIFA. OREI Principal Investigators meeting. Biological, environmental, and

economic implications of strategic grazing in organic systems - Type: Conference Papers and Presentations Status: Other Year Published: 2014 Citation: Menalled, F. 2014. Iowa State University. Department of Agronomy. Invited presentation: Combining systematic and systemic research to guide sustainable agriculture - Type: Conference Papers and Presentations Status: Other Year Published: 2014 Citation: Menalled, F. 2014. University of British Columbia. Faculty of Land and Food Systems Invited presentation: Social and natural sciences, partners in the design of sustainable food systems - Type: Conference Papers and Presentations Status: Other Year Published: 2013 Citation: Menalled, F. 2013. Montana State University. Department of Land Resources and Environmental Sciences. Invited presentation: Integrated management of agricultural weeds. - Type: Conference Papers and Presentations Status: Awaiting Publication Year Published: 2017 Citation: Adhikari, S., L. A. Burkle, K. M. O'Neill, and D. K. Weaver, and F. D. Menalled. 2017. Impacts of dryland farming systems on bee communities and bee-flower networks in the Northern Great Plains. Entomological Society of America Meeting, Denver, CO, USA (November 5-8) - Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Adhikari, S., L. Burkle, K. M. O'Neill, D. K. Weaver, and F. D. Menalled. 2017. Impacts of dryland farming systems on bee communities and bee-flower networks in the Northern Great Plains. Entomological Society of America annual meeting. November 5-8. Denver, CO. - Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Orloff, N. F. Menalled, and J. Mangold. 2017. A meta-analysis of field bindweed (*Convolvulus arvensis*) and Canada thistle (*Cirsium arvense*) management in organic agricultural systems. Western Society of Weed Science Annual Meeting. March 13-16. Coeur D'Alene, ID. - Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Orloff, N., J. Mangold, F. Menalled, and Z. Miller. 2016. A meta-analysis of Canada thistle (*Cirsium arvense*) management in organic perennial systems. 4th Conference of the Northern Rockies Invasive Plant Council. October 19, 2016. Boise ID. - Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Hogstad, S.K., Gramig G.G., Carr P.M. 2017. Weed communities shift in response to organic no-till integrated with grazing. Weed Science Society of America Annual Meeting, March 6-9, Tucson, AZ. 57:143. - Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Carr, P.M., Gramig, G.G., Hogstad, S.K. 2016. Long-term organic zero-tillage challenges in the U.S. Great Plains. Proceedings of the American Society of Agronomy 79:230-6. - Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Ishaq, S.L., S.P. Johnson, Z.J. Miller, E.A. Lehnhoff, S.K. Olivo, C.J. Yeoman, and F.D. Menalled, F.D. 2016. Farming systems modify the impact of inoculum on soil microbial diversity. American Society for Microbiology (ASM), Boston, MA, June 2016. - Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Adhikari, S., L. A. Burkle, K. M. O'Neill, and D. K. Weaver, and F. D. Menalled 2016. Effects of agricultural management systems on natural habitat distribution and pollinators in the Northern Great Plains (poster). Graduate Student Summit Research Rendezvous Poster Session MSU- Graduate School, Bozeman, MT (September 14- 15). - Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Adhikari, S., L. A. Burkle, K. M. O'Neill, and D. K. Weaver, A. J. Hansen, A. Adhikari, and F. D. Menalled 2016. Effects of agricultural management systems on natural habitat distribution in the Northern Great Plains: Implications for pollinators. Ecological Society of America Meeting in Fort Lauderdale, FL, USA (Aug 7-12). - Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Bhowmik, A., A.M. Fortuna, L.J. Cihacek, A.I. Bary, P.M. Carr, and C.G. Cogger. 2015. Potential carbon sequestration and nitrogen cycling in long term organic management systems. Proceedings of the American Society of Agronomy 292-18. - Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Bhowmik, A., A.M. Fortuna, L.J. Cihacek, and P.M. Carr. 2015. Use of laboratory incubation techniques for estimate GHG footprints from clean and no-tillage organic agroecosystems. Proceedings of the American Society of Agronomy 64-5. - Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Gramig G.G. 2014. Grazing and disturbance effects on insect seed predators in organic field crops. Proceedings of the Western Society of Weed Science 67:046. - Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Carr P.M., Gramig G.G., Hogstad S. 2015. Continuous zero-till organic wheat production: defining the limits. Proceedings of the American Society of Agronomy 78:64-7. - Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Gramig G.G., Carr P.M. 2015. Weed seed predation dynamics in no-till and tilled organic wheat. Proceedings of the Western Society of Weed Science 68:049. - Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Bhowmik, A., Cihacek, L., and A.M. Fortuna. 2014. Managing reactive nitrogen in long term clean till and no till organic agroecosystems. Proceedings of the American Society of Agronomy 314-5. - Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Johnson, S., P.R. Miller, F. Menalled, and Z. Miller. 2014. Reducing tillage on organic dryland farms in the Northern Great Plains with grazers. Agronomy Society of America Annual Meeting. Long Beach CA November 3, 2014 - Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: McKenzie, S; H.B. Goosey, K.M. O'Neill, and F.D. Menalled. 2014. What is the effect of sheep grazing for cover-crop termination on associated biodiversity? Western Section of American Society of Animal Science. San Angelo, TX. June 20, 2014.

PROGRESS

2015/09 TO 2016/08 Target Audience: Our audience includes farmers, ranchers, agricultural professionals, and extension agents with interest in dryland sustainable organic agriculture. We also target undergraduate and graduate students, and elementary and secondary rural schoolteachers interested in sustainable agriculture, animal production, and organic cropping systems. Changes/Problems: The only problem we experienced was that in 2015 the integrity of this site was compromised as the cooperating farmer chisel plowed all plots prior to sampling. Soil cores were collected but no difference in plant available N were found. All other proposed activities were conducted as planned and we foresee no major changes during the next reporting period. What opportunities for training and professional development has the project provided? Several undergraduate and graduate students, research technicians and post-doctoral associates collaborated in this project. Undergraduate students: Ali Thornton, Sam Leuthold, Andrew Thorson, Kyla Crisp, Lazaro Vinola Current MS graduate: Molly Butler, Tessa Scott, Ranabhat Nar Graduated MS students: Sean McKenzie, Stephen Johnson, Jasmine Westbrook Current PhD students: Subodh Adhikari Research technicians: Sean McKenzie, Stephen Johnson, Devon Ragen, Jeff Holmes Post-doctoral Research Associates: Judit Barroso, Erik Lehnhoff, Timothy Seipel, and Suzanne Ishaq How have the results been disseminated to communities of interest? Extension/outreach. Between 2013 and August 2016, results were presented at 14 state extension meetings, directly reaching more than 700 participants. At the regional and international level, results were presented at the 2015 NCAA meeting (25 attendants) and the 2015 Ontario Fruit and Vegetable Convention (65 attendants). Results were showcased in the eOrganic Webinar Innovative Approaches to Extension in Organic and Sustainable Agriculture (148 attendants) on April 7, 2015 and will be presented at the eOrganic Webinar Targeted Sheep Grazing in Organic Systems on October 11, 2016. We produced the video MSU organic farming study finds diverse benefits (<https://www.youtube.com/watch?v=Y5w25UgWMTs>), 1300 views as August 24, 2016. As part of our program to train teacher in organic and sustainable agriculture, we produced the article Science in action: Biological and ecological principles of urban agriculture to be published in Designing urban agriculture programs to improve STEM learning and teaching. Patchen et al. eds. Springer and gave an invited presentation on this topic at the 2016 National Association Research in Science Teaching meeting. What do you plan to do during the next reporting period to accomplish the goals? We plan to finalize data analysis on the impact of targeted grazing on biological and environmental variables. We expect that all our current graduate students will complete their MS and PhD programs. Within the next twelve months we will submit at least 4 articles to be submitted to peer-reviewed professional journals. We plan to We will continue developing education and outreach opportunities on organic agriculture and re-integration of sheep grazing into dryland farming systems.

2014/09 TO 2015/08 Target Audience: Our targeted audience included framers, ranchers, agricultural professional, and extension agents with interest dryland in sustainable organic agriculture. We also targeted undergraduate and graduate students, and elementary and secondary rural schoolteachers interested in sustainable agriculture, animal production, and organic cropping systems Changes/Problems: All proposed activities were conducted as planned and we foresee no major changes during the next reporting period. What opportunities for training and professional development has the project provided? Several undergraduate students, graduate students, research technicians and post-doctoral associates collaborated in this project. Undergraduate students: Ali Thornton, Sam Leuthold, Andrew Thorson, and Kyla Crisp Master-level students: Molly Butler, Tessa Scott, Jasmine Westbrook Graduated Master level students: Sean McKenzie, Stephen Johnson PhD-level Students: Ranabhat Nar and Subodh Adhikari Research technicians: Devon Ragen and Jeff Holmes Post-doctoral associate: Judit Barroso, Erik Lehnhoff, and Timothy Seipel. How have the results been disseminated to communities of interest? In 2015, results of our study were presented at 7 outreach - extension presentations reaching approximately 359 participants (see above. Obj 7). Among the communities of interest to whom we disseminated our results are 1) Montana Organic Association, 2) National Association of County Agricultural Agents, and 3) Ontario Fruit and Vegetable Association. What do you plan to do during the next reporting period to accomplish the goals? We will finalize our field studies on the impact of targeted grazing on biological and environmental variables at our North Dakota and Montana field sites. We plan to analyze the data and we we will continue developing education and outreach opportunities on organic agriculture and re-integration of sheep grazing into dryland farming systems.

2013/09 TO 2014/08 Target Audience: Our targeted audience included framers, ranchers, agricultural professional, and extension agents with interest dryland in sustainable organic agriculture. We also targeted undergraduate and graduate students, and elementary and secondary rural schoolteachers interested in sustainable agriculture, animal production, and organic cropping systems. Changes/Problems: All proposed activities were conducted as planned and we foresee no major changes during the next reporting period. What

opportunities for training and professional development has the project provided? Several undergraduate students, graduate students, research technicians and post-doctoral associates collaborated in this project. Undergraduate students: Ariella Tuttle, Emily Griswold, Madison Nixon, Ali Thirton, and Shane Stoner. Master-level students: Sean McKenzie, Stephen Johnson, Molly Butler, and Jasmine Westbrook. PhD-level Students: Ranabhat Nar, and Subodh Adhikari Research technicians: Devon Ragen and Jeff Holmes Post-doctoral associate: Judit Barroso, Erik Lehnhoff. Our research has been discussed in the following undergraduate and graduate courses: ENSC 454. Landscape Pedology. Offered by Dr. Stephanie Ewing. This undergraduate course utilized the Ft. Ellis site to conduct assess the impact of management systems on soil health. Enrollment: 35 students SFBS 296. Summer Practicum Course. This undergraduate course utilized the Towns Harvest site to assess approaches to sustainable agriculture including the integration of sheep grazing into vegetable precaution. 20 students ENSC410/LRES 510. Biodiversity Survey and Monitoring. This undergraduate course utilized the Ft. Ellis field site to assess the impact of management systems on biodiversity. Enrollment: on 14 students MSU AGSC 428/ LRES 529 Sustainable Cropping Systems. Offered by Dr. P. Miller. Dr. Menalled and Dr. Zach Miller provided guests lectures where ecologically based weed management and integrated crop -- livestock systems were discussed. Enrollment: 30 students. ANRN 222. Livestock in Sustainable Systems. Dr. Hatfield revised concepts of sustainable livestock production. Enrollment: 99 students. MSU ANSC 232 Sheep Practicum. Dr. Hatfield is currently teaching this hands-on practicum course. Among the activities, students to work with data from the Montana Diagnostic Center to compare management system's impact on internal parasite loads. Enrollment: 15 students. MSU LRES 110. Introduction to Land Resources and Environmental Sciences. Dr. Menalled (PI of this project) provided guests lectures on ecologically based weed management and integrated crop -- livestock systems in organic fields. Also, students visited the Ft. Ellis Research Farm. Enrollment: 95 students. MSU ANSC 222 Sustainable and Organic Livestock Production. In this new course Dr. Hatfield considers all aspects of sustainable and organic livestock production systems. Part of the course focus on incorporating grazing livestock into sustainable and organic farming systems. Enrollment: 200 students MSU AGSC 401 Integrated Pest Management. A lecture will be giving at the end of the Fall 2013 semester. Enrollment: 25 students. DSU PLSC 110 World Food Crops. Offered by Dr. Carr. A walking tour was provided to students on 11 Sep 2013. Objectives of the course were discussed and students observed project treatments, including grazed plots, that were in place on that day. Discussion of the organic no-till concept and the importance of livestock grazing in that system were discussed, as well as general organic farming requirements and principles. The entire presentation/discussion occurred over a 30 minute time period. Enrollment: 18 students. How have the results been disseminated to communities of interest? In 2014, results of our study were presented at several outreach -- extension presentations. Among them, 1) 130th Annual Montana Wool Growers Convention, 2) 2014 Northwest Scientific Association/Plum Creek Lecture Series conference, 3) 20th Annual MSU Student Research Celebration, 4) 2014 Montana Nutrition Conference and Livestock Forum, 5) 2014 MSU Northern Agricultural Research Center Field Day, 6) 1) Crops and Weeds Field Day at MSU's Post-Farm, and 7) Montana Organic Association national meeting. What do you plan to do during the next reporting period to accomplish the goals? We will continue with our field studies on the impact of targeted grazing on biological and environmental variables at our North Dakota and Montana field sites. We will continue developing education and outreach opportunities on organic agriculture and re-integration of sheep grazing into dryland farming systems.

2012/09 TO 2013/08 Target Audience: Our primary audience included framers, ranchers, agricultural professional, and extension agents with interest dryland in organic agriculture. We also targeted undergraduate and graduate students, and elementary and secondary rural schoolteachers interested in sustainable agriculture, animal production, and organic cropping systems. Changes/Problems: All proposed activities were conducted as planned and we foresee no major changes during the next reporting period. What opportunities for training and professional development has the project provided? Several undergraduate students, graduate students, research technicians and post-doctoral associates collaborated in this project. Undergraduate students: Lori Saulsbury, Christian Larson, Ariella Tuttle, Emily Griswold, and Shane Stoner. Master-level students: Sean McKenzie, Stephen Johnson, Molly Butler, and Jasmine Westbrook. PhD-level Students: Ranabhat Nar, and Subodh Adhikari Research technicians: Devon Ragen and Jeff Holmes Post-doctoral associate: Judit Barroso The experience obtained in our first year of this research has been discussed in the following undergraduate and graduate courses: MSU AGSC 428/ LRES 529 Sustainable Cropping Systems. Offered by Dr. P. Miller. Dr. Menalled and Dr. Zach Miller provided guests lectures where ecologically based weed management and integrated crop -- livestock systems were discussed. Enrollment: 30 students. MSU ANSC 232 Sheep Practicum. Dr. Hatfield is currently teaching this hands-on practicum course. Among the activities, students to work with data from the Montana Diagnostic Center to compare management system's impact on internal parasite loads. Enrollment: 15 students. MSU LRES 110. Introduction to Land Resources and Environmental Sciences. Dr. Menalled (PI of this project) and Dr. Zach Miller,(Co-PI of this project) provided guests lectures on ecologically based weed management and integrated crop -- livestock systems in organic fields. Also, students visited the Ft. Ellis Research Farm. Enrollment: 85 students. MSU ANSC 222 Sustainable and Organic Livestock Production. In

this new course Dr. Hatfield considers all aspects of sustainable and organic livestock production systems. Part of the course focus on incorporating grazing livestock into sustainable and organic farming systems. Enrollment: 200 students MSU AGSC 401 Integrated Pest Management. A lecture will be giving at the end of the Fall 2013 semester. Enrollment: 25 students. DSU PLSC 110 World Food Crops. Offered by Dr. Carr. A walking tour was provided to students on 11 Sep 2013. Objectives of the course were discussed and students observed project treatments, including grazed plots, that were in place on that day. Discussion of the organic no-till concept and the importance of livestock grazing in that system were discussed, as well as general organic farming requirements and principles. The entire presentation/discussion occurred over a 30 minute time period. Enrollment: 18 students. The ND research plots, located at the Dickinson Research Extension Center, can be easily reached by North Dakota State University students, where they can see the experimental design and sheep grazing. Finally, Dr. Z. Miller gave a presentation at the Crow reservation to eight elementary and middle school teachers on agroecology and pest management. These teachers were selected for their leadership role in their communities. How have the results been disseminated to communities of interest? In spite the early stage of our research and outreach activities, we have been very active in reaching farmers and public in general. The purpose and preliminary research findings were presented in three field days: 1) Town Harvest Field Day-a certified organic garden- organized by the Montana Organic Association (MOA) on June 29, 2013; 2) Farmers Union Field Day at MSU's Post-Farm, Four Corners, MT, on June 9, 2013-attendance: 50 people; and 3) Crops and Weeds Field Day at MSU's Post-Farm, Four Corners, MT, on June 27, 2013-attendance: 70 people. Participants attended presentations and received a booklet with summaries of different studies related to crop and weed management, including the research study of Targeted Grazing project. Growers, agricultural professionals, Extension agents, and research and education staff from the dean of the College of Agriculture Office constituted the audience. The audience was very receptive of the presentation "Integrated Crop-Livestock Production", addressing the study of the current project. Several questions were posed about the time of grazing, the use sheep in tilled fields, field size, and spot grazing. A survey about participant's perception of the use of sheep to control weeds was distributed. Results of this survey are being analyzed by the social scientist of Targeted Grazing team. In addition to the field days, Targeted Grazing project participated in the Montana Science and Engineering Festival hold at Bobcat Stadium on September 21, 2013. MSU science and engineering faculty, students, and local business professionals offered events and hands-on activities free and open to the public of all ages. Approximately 2,000 visitors attended the Festival. Sheep and posters summarizing the research principles of our research attracted the attention of the public. Even one visitor said "I did not know you could do scientific research with sheep". A news released in MSU's Plant Science and Plant Pathology departmental newsletter followed this event. The project Director will present a talk on Life-stock integration to weed management at the Montana Science Olympiad, on November 26. The Montana Science Olympiad involves approximately 1,800 middle and high school students from every corner in Montana. An integrated approach to weed management involving livestock raised interest among producers. "If sheep will be a positive influence for grain production and weed management, then I anticipate a lot of interest among not only organic but also non-organic growers in what we are doing. " In addition, having experiments in growers' fields is another way to involve a community that would direct benefit from the research findings of the project "to bring growers into project, like Bob \Quinn\, they appreciate this." Moreover our research project already is inspiring future studies integrating life stock and crop-based research. "Although we are not collecting animal data in the project in North Dakota, the \director of the Research Extension Center\ recognizes the value of these data and would like to collect data in the future... Doing this project will bring new ideas and procedures for future grant proposals and research. " In addition, our project has a positive impact on the Dickinson's community due to the location of the Center "many people walk by \the Research Extension Center\ and see the sheep. This is important for the community and is good exposure for the Center because it showcases the organic research that we are conducting. It is a very good publicity for the Center." Due to the expertise of our team in organic crop production methods, a group of organic farmers approached the project's leadership to develop a research program to address the management of bindweed in Northeast Montana. Different options were explored, such as: an update of historical control of the weed, use of livestock, cultivars, soil nutrition, biological control, green manure, and cover crops. This group of farmers has been making observations by their own and came to seek help from the scientists. For example, organic growers suggested the use of cattle as a possible way to control bindweed because they found that cattle "like" bindweed. Experiences on the use of livestock to manage weeds from Fort Elis, Post Farm and Town Harvest were shared to produce hypotheses of the feasibility to use cattle to control bindweed. Also were discussed the use of crop rotation, till-organic management, graze, and non-till classic management to control bindweed and thistle. Targeted Grazing faculty proposed to develop a research project to find a solution to the management of bindweed following the findings of the current project, such that it will result in an accumulated long-term research of at least five years of data. Farmers agreed to distribute a survey about current and historical methods of weed control. What do you plan to do during the next reporting period to accomplish the goals? We will continue with our field studies on the impact of targeted grazing on biological and

environmental variables at our North Dakota and Montana field sites. We will continue developing education and outreach opportunities on organic agriculture and re-integration of sheep grazing into dryland farming systems.

IMPACT

2015/09 TO 2016/08 What was accomplished under these goals? 1. Effects of grazing and tillage on soil quality Dickinson, North Dakota In 2014, 2015, and 2016 spring soil NO₃-N levels were higher in the organic till (OT) than the organic grazed (OG) system. This can be due to more severe weed populations for OG which likely depressed NO₃-N levels and tillage events may have stimulated organic N mineralization in the OT, which led to elevated soil NO₃-N levels. NH₄-N levels were not sensitive to management system but lower than the NO₃-N concentrations. Potential mineralized N (PMN) varied across reps and within individual samples. Triplicate analysis were conducted to improve detection abilities but within sample CV averaged 20-25% and may have masked potential differences between management systems. Big Sandy, Montana In the first two years of this study, soil NH₄-N and PMN concentration were rather insensitive to management practices. Although, the OG system produced slightly higher NH₄-N concentrations than the OT one within the 10-20 and 20-30 cm layers, the differences were not large. In the third year, the integrity of this site was compromised as the cooperating farmer chisel plowed all plots prior to sampling. Soil cores were collected but no difference in plant available N were found. 2. Crop yield and quality. Dickinson Between 2013 and 2016, wheat yield ranged from 2450 to 4650 kg/ha in OT plots and was 60 to 90% lower in organic no-till plots, depending on the year ($P < 0.05$). Pea yield averaged from 850 to 3940 kg/ha in OT plots and was 45 to 90% lower in no-till plots. Failure of cover crops to produce weed suppressive mulch, along with an inability of acetic acid applications and grazing to kill perennial and established annual weeds may have caused these results. Big Sandy In 2014, our farmer cooperater seeded winter wheat instead of spring cereal and it was not worth his time to adjust seed depth with respect to the six 40 x 40 ft grazed sweet clover plots, which resulted in wheat seed placement on the soil surface and near zero wheat establishment. Consequently response crop yield results were not possible in 2015. Yield measurement of the 2015 OG and OT occurred on August 22, 2016. We are processing the samples and will present the results in the final report. 3. Impacts of targeted sheep grazing on associated biodiversity Dickinson Perennial weeds \Canada thistle (*Salsola kali*), field bindweed (*Convolvulus arvensis*), and dandelion (*Taraxacum officinale*) dominated the no-till systems, but were largely absent from OT. Overall weed pressure increased over time with four no-till plots with no initial population of Canada thistle becoming heavily infested by 2016. Conversely, Canada thistle was essentially eliminated by 2016 in one of three OT plots with established populations at the beginning of the study. Temporal availability of weed seeds varied between systems but seed removal did not. Carabid activity-density correlated with weed seed rain. Big Sandy Confirming our previous observations, weed species richness and diversity did not differ between previously OG and OT plots. In both treatments, the two most abundant species observed in 2016 were field bindweed and Canada thistle. Between 2013 and 2015 we compared pollinator and carabid beetle communities, and bumblebee (*Bombus impatiens*) colonies growth between organic and conventional wheat fields. Preliminary results showed similar species abundance and richness between systems. The relative growth rate of bumblebee colonies was higher in organic than in conventional fields (conventional = 0.05 ± 0.003 and organic = 0.06 ± 0.002 g g⁻¹ wk⁻¹), probably due to the greater amount of pollen and nectar provided via weed diversity. Three times during the summer we assessed disease incidence. We found no difference in disease incidence or severity between OT and OG plots on matured stage of spring wheat ($P > 0.05$). Fort Ellis, MT Between 2013 and 2015 we failed to detect any difference in carabid activity density, species diversity, and species richness between conventional no-till, OT, and OG systems and between crops. However, a multivariate analysis indicated that carabid communities differed among systems. Between 2013 and 2014, we observed a change in weed community abundance and composition. We are processing the 2016 data and will analyze the complete data set within the next 6 months. 4. Compare lambing and lamb finishing systems on finishing performance, internal parasite infestations, carcass quality, and product shelf life We compared lamb growth and carcass characteristics under four management systems during the first two years of this project: 1) high energy - 60% barley, 2) moderate energy - 70% alfalfa, 3) continuous graze, and 4) rotational graze. Body weight and rib eye area did not differ between barley and alfalfa diets but it was lower in both grazing treatments. 5. Enterprise budgets of integrating organic sheep and crop production in semiarid environments. We conducted 1) a production budget for a representative producer that evaluates net returns for a five-year system across Conventional no-till, OT, and OG systems, and 2) net returns under many possible economic environments based on historical data of input costs, market prices, and yield variability. Five-year returns for the conventional and the transitional OT systems were nearly identical, suggesting that in the early stages of organic transition farmers can expect minimal economic declines. The OG system resulted in economic losses over the five year period due declines in yields across, a 4% point reductions in winter wheat protein levels, and fencing costs. If fencing materials and ownership costs were borne by the

sheep producer, the five-year returns were approximately \$361 per acre which is just over 50% of the most profitable approach. A 5,000 simulation of net returns under possible economic environments provided qualitatively similar results to those using existing market data. 6. Develop training opportunities and educational resources on sustainable organic practices Our research has been discussed in the following courses: SFBS 296. Summer Practicum Course. This undergraduate course utilized the Towns Harvest site to assess approaches to sustainable agriculture including the integration of sheep grazing into vegetable production. ENSC410/LRES 510. Biodiversity Survey and Monitoring. This undergraduate course utilized the Ft. Ellis field site to assess the impact of management systems on biodiversity. MSU AGSC 428/ LRES 529 Sustainable Cropping Systems. Offered by Dr. P. Miller. Topic included ecologically based weed management and integrated crop - livestock systems. Enrollment: 30 students. ANRN 222. Livestock in Sustainable Systems. Dr. Hatfield revised concepts of sustainable livestock production. Enrollment: 99 students. MSU LRES 110. Introduction to Land Resources and Environmental Sciences. Dr. Menalled provided guests lectures on ecologically based weed management and integrated crop - livestock systems in organic fields. Also, students visited the Ft. Ellis Research Farm. Enrollment: 95 students. 7. Design and implement outreach programs on integrated crop/livestock production systems Between 2013 and August 2016, results were presented at 14 state extension meetings, directly reaching more than 700 participants. At the regional and international level, results were presented at the 2015 NCAA meeting (25 attendants) and the 2015 Ontario Fruit and Vegetable Convention (65 attendants). Results were showcased in the eOrganic Webinar Innovative Approaches to Extension in Organic and Sustainable Agriculture (148 attendants) on April 7, 2015 and will be presented at the eOrganic Webinar Targeted Sheep Grazing in Organic Systems on October 11, 2016. We produced the video MSU organic farming study finds diverse benefits (<https://www.youtube.com/watch?v=Y5w25UgWMTs>), 1300 views as August 24, 2016. **PUBLICATIONS (not previously reported):** 2015/09 TO 2016/08 1. Type: Journal Articles Status: Submitted Year Published: 2016 Citation: Bhowmik, A., A. Fortuna, L.J. Cihacek, A.I. Bary, P.M. Carr, and C.G. Cogger. Potential carbon sequestration and nitrogen cycling in long term organic management systems. *Renew. Agric. and Food Sys.* 2. Type: Book Chapters Status: Awaiting Publication Year Published: 2016 Citation: Grimberg, B. and F. Menalled. In Press. Science in action: Biological and ecological principles of urban agriculture. In *Designing urban agriculture programs to improve STEM learning and teaching*. Patchen, A. Barnett, M. Esthers, L., and Knobloch, N., eds. Springer 3. Type: Journal Articles Status: Published Year Published: 2015 Citation: Goosey, H.B., S. C. McKenzie, M. G. Rolson, K. M. O'Neill, and F. Menalled. 2015. Impacts of contrasting alfalfa (*Medicago sativa*) production systems on the drivers of carabid beetle (Coleoptera: Carabidae) community dynamics. *Environmental Entomology* 44:1052-1064. 4. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Carr, P., G. Gramig, and S. Hodgstad. Continuous zero-till organic wheat production: defining the limits. In 2015 Annual Meeting Abstracts, ASA, CSSA, and SSSA, Madison, WI. 5. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: S. Adhikari, L.A. Burkle, K.M. O'Neill, D.K. Weaver, A.J. Hansen, A. Adhikari, and F.D. Menalled. 2016. Effects of agricultural management systems on natural habitat distribution in the Northern Great Plains: Implications for pollinators. Paper presented on 101st Ecological Society of America meeting (Aug 7-12, 2016) at Fort Lauderdale, FL 6. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Ishaq, S.L., S.P. Johnson, Z.J. Miller, E.A. Lehnhoff, S.K. Olivo, C.J. Yeoman, and F.D. Menalled, F.D. Farming Systems Modify The Impact Of Inoculum On Soil Microbial Diversity. American Society for Microbiology (ASM), Boston, MA, June 2016. 7. Type: Journal Articles Status: Published Year Published: 2016 Citation: Barsotti, J.L., Sainju, U.M., Lenssen, A.W, Miller, Z.J. and Hatfield, P.G. 2016. Sheep grazing enhances coarse relative to microbial organic carbon in dryland cropping systems. *Sustainable Agricultural Research*. 5:1-14. doi: 10.5539/sar.v5n2p1. 8. Type: Conference Papers and Presentations Status: Awaiting Publication Year Published: 2016 Citation: P.M. Carr, S. Briar, G. Gramig, F. Menalled, and P. Miller. 2016. Current status and future outlook of organic conservation tillage in the U.S. Great Plains Region. International seminar on emerging trends in organic farming and sustainable agriculture to be held on 29, 30 and 31 December 2016 at Mahatma Gandhi University, Kottayam, Kerala, India. 9. Type: Journal Articles Status: Awaiting Publication Year Published: 2016 Citation: Johnson, S., Z. Miller, P. Miller, E. Lehnhoff, and F. Menalled. In Press. Cropping systems modify soil biota effects on wheat (*Triticum aestivum* L.) growth and competitive ability. *Weed Research* 10. Type: Journal Articles Status: Accepted Year Published: 2016 Citation: Ishaq, S., S. Johnson, Z. Miller, E. Lehnhoff, S. Olivo, C. Yeoman, and F. Menalled. Accepted with Revisions. Impact of cropping systems, soil inoculum, and plant species identity on soil bacterial community structure. *Microbial Ecology* 11. Type: Journal Articles Status: Awaiting Publication Year Published: 2016 Citation: McKenzie, S., H. Goosey, K. M. O'Neill, and F. Menalled. In Press. Integration of sheep grazing for cover crop termination into market gardens: Agronomic consequences of an ecologically-based management strategy. *Renewable Agriculture and Food Systems*

2014/09 TO 2015/08 What was accomplished under these goals? 1. Effects of sheep grazing and mechanical tillage on soil. We continue collecting soil cores from the organic till and grazed systems, separated into 0-10, 10-20, 20-30, and 30-60 cm depth segments and analyzed for inorganic N (NO₃-N and NH₄-N) and potential

mineralizable N (PMN). At the Dickinson site, soil NH₄-N and PMN concentrations were not affected by management system. Soil inorganic NH₄-N concentrations were considerably lower than the NO₃-N concentrations. The PMN results revealed considerable variance across the five reps and within individual soil samples. At the Big Sandy site, soil NH₄-N and PMN concentration were generally insensitive to management practices. Although, the grazed system produced slightly higher NH₄-N concentrations than the tilled system within the 10-20 and 20-30 cm layers, the differences in concentration were not very large and did not greatly impact the plant available N pools.

2. Compare crop yield and quality between targeted sheep grazed systems and tillage-based systems. Dickinson, ND. Wheat yield averaged 2450 kg ha⁻¹ in conventional-till plots in 2012, 3820 kg ha⁻¹ in 2013, 4650 kg ha⁻¹ in 2014, and 4150 kg ha⁻¹ in 2015. Wheat yield was 58% lower under no-till in 2012, 45% in 2013, 87% in 2014, and 90% in 2015 ($P < 0.05$). While no difference was detected in pea yield under conventional-till vs. no-till in 2012, pea yield was 67% lower under no-till in 2013, 36% in 2014, and 90% in 2015. During those four years, pea yield averaged 850 kg ha⁻¹ under conventional-till in 2012, 1785 kg ha⁻¹ in 2013, 2235 kg ha⁻¹ in 2014, and 3940 kg ha⁻¹ in 2015. Big Sandy, MT. Our farmer cooperator seeded winter wheat instead of planned spring cereal. It was not worth cooperator's time to adjust seed depth from tilled soil with respect to six 40 x 40 ft grazed sweet clover plots, which resulted in wheat seed placement on the soil surface and near zero wheat establishment. Consequently response crop yield results were not possible in 2015. Spring pea was grazed in 2015 and it is hoped that with spring cereal planting it will be possible for cooperator to achieve proper seed to soil contact in grazed 40 x 40 ft plots.

3. Assess the impacts of targeted sheep grazing on weeds, pathogens, and insect Dickinson, ND. We continued assessing annual and perennial weeds in no-till and tilled organic plots. Late season assessment of perennial weeds indicated that no-till plots contained substantial infestations of Canada thistle, field bindweed, and dandelion, but that these species were largely absent from conventionally tilled plots. Additionally, occurrence of these perennial weed species appears to have increased over the three years that data have been collected. Our results indicate that this increase in perennial weeds translate into a significant reduction in crop yield occurring by year 5 or 6 under continuous no-till compared with conventional-till systems under organic management in western North Dakota. We also compared weed seed rain, weed seed predation, and invertebrate activity-density across systems. The temporal availability of weed seeds varied between systems but weed seed removal did not. Insect activity was not affected by tillage type and carabid activity correlated with weed seed rain. Big Sandy, MT. Weed species richness or Simpson's diversity did not differ between grazed and tilled plots. *Medicago sativa* grew as one of the most abundant weeds in this field both treatments. Nonetheless, there were no differences between grazed and tilled treatments in terms of *M. sativa* biomass in 2014 after termination treatments. Also, method of cover crop termination did not alter weed communities in the crop phase. To evaluate insect communities we placed a total of 36 total pollinators traps every 5m on the 55m transects within originally and conventionally managed wheat fields. Carabid beetles were evaluated by placing 9 pitfall traps at each transect. Samples were obtained four times during the growing season. There was no significant difference in diversity index and bee abundance between management systems. However, the relative growth rate of *Bombus impatiens* (common eastern bumblebee) colonies was higher in organic than in conventional fields (conventional = 0.05 ± 0.003 and organic = 0.06 ± 0.002 g g⁻¹ wk⁻¹). Higher growth rate in organic fields may be due to the greater amount of pollen and nectar provided via weed diversity. Hence, greater floral diversity in organically managed wheat cropping can enhance pollination services.

Disease incidence. Three times during the summer disease incidence was assessed by collecting five plants with roots. Disease incidence was recorded on the basis of symptoms in different parts of the plants with no difference as a function cover crop termination strategy.

4. Compare lambing and lamb finishing systems on finishing performance, internal parasite infestations, carcass quality, and product shelf life. We compared lamb growth and carcass characteristics under four management systems: 1) high energy - 60% barley, 2) moderate energy - 70% alfalfa, 3) continuous graze, and 4) rotational graze. Results indicated that while body weight and rib eye area did not differ between barley and alfalfa diets, it was significantly lower in both grazing treatments.

5. Develop enterprise budgets of integrating organic sheep and crop production in semiarid environments. A preliminary analysis suggested that growers that terminate their cover crops through strategic grazing could expect approximately \$27 to \$44 ha⁻¹ under a grazing lease.

6. Develop training opportunities and educational resources on sustainable organic practices Our research has been discussed in the following undergraduate and graduate courses: SFBS 296. Summer Practicum Course. This undergraduate course utilized the Towns Harvest site to assess approaches to sustainable agriculture including the integration of sheep grazing into vegetable production. ENSC410/LRES 510. Biodiversity Survey and Monitoring. This undergraduate course utilized the Ft. Ellis field site to assess the impact of management systems on biodiversity. MSU AGSC 428/ LRES 529 Sustainable Cropping Systems. Offered by Dr. P. Miller. Topic included ecologically based weed management and integrated crop - livestock systems were discussed. Enrollment: 30 students. ANRN 222. Livestock in Sustainable Systems. Dr. Hatfield revised concepts of sustainable livestock production. Enrollment: 99 students. MSU LRES 110. Introduction to Land Resources and Environmental Sciences. Dr. Menalled (PI of this project) provided guest lectures on ecologically based weed management and integrated crop - livestock systems in organic fields. Also, students visited the Ft. Ellis Research Farm. Enrollment: 95 students.

7. Design and

implement transformative outreach programs on integrated crop/livestock production systems that are economic and environmentally sustainable. In 2015, results of this project have been presented at the following extension/outreach meetings: 2/18/2015. Ontario, Canada. Ontario Fruit and Vegetable Convention. 65 attendants. Using sheep to manage weeds and cover crops in horticultural systems. 30 minutes. 3/5/2015. Bozeman, MT. Pathway to College. 7 attendants. Agriculture and ecology. 60 minutes. 3/27/2015. Bozeman, MT. Pathway to College. 9 attendants. Agriculture and ecology. 60 minutes. 4/7/2015. Webinar eOrganic. 148 attendants. Innovative Approaches to Extension in Organic and Sustainable Agriculture. 60 minutes. 7/12/2015. Sioux Falls, SD. NACAA meeting. 25 attendants. Transitioning to organic. 30 minutes. 11/3/2015. Bozeman, MT. Soil health workshop. 45 attendants. Using sheep to manage weeds and cover crops and reduce tillage. 60 minutes. 12/4/2005. Bozeman, MT. Montana Organic Association. 60 attendants. Integrating crop and livestock production in organic systems. 120 minutes. **PUBLICATIONS (not previously reported):** 2014/09 TO 2015/08

1. Type: Journal Articles Status: Published Year Published: 2015 Citation: Miller, Z.; F. Menalled, U.M. Sainju, A.W. Lenssen, and P.G. Hatfield. 2015. Integrating sheep grazing into cereal-based crop rotations: Spring wheat yields and weed communities. *Agronomy Journal* 107: 104-112
2. Type: Journal Articles Status: Awaiting Publication Year Published: 2016 Citation: McKenzie, S., H. Goosey, K. M. O'Neill, and F. Menalled. In Press. Integrating livestock for cover crop termination in horticultural vegetable production: Impacts on weed and ground beetle (Coleoptera: carabidae) communities. *Agriculture, Ecosystems and Environment*.
3. Type: Journal Articles Status: Awaiting Publication Year Published: 2016 Citation: McKenzie, S, H. Parkinson, M. Burrows, S. Ahmed, and F. Menalled. In Press. Perceptions, previous knowledge, and needs differ across agricultural. *PLOS ONE*.
4. Type: Journal Articles Status: Awaiting Publication Year Published: 2016 Citation: Barroso, J., Z. Miller, E. Lehnhoff, P. Hatfield, and F. Menalled. In Press. Impacts of cropping system and management practices on the assembly of weed communities. *Weed Research*.
5. Type: Theses/Dissertations Status: Published Year Published: 2016 Citation: Johnson, S.P. 2015. Effects of organic and conventional cropping systems on plant diversity and plant soil feedbacks. MS thesis. Montana State University
6. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Adhikari, S., L. Burkle, K. O'Neill, D. Weaver, and F. Menalled. 2015. Impacts of farm management practices on pollinator community and pollination services in the Northern Great Plains. 2015 Entomological Society of America Annual Meeting. November 16-18, 2015. Minneapolis, MS.
7. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Nar B. Ranabhat, N., M. Burrows, Z. Miller, E. Lehnhoff, and F. Menalled. 2015. Impact of cover crop termination methods on diseases of wheat and lentil. American Phytopathological Society and APS Pacific Division Joint meeting, Pasadena, CA, August 2015
8. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Menalled, F., S. McKenzie, H. Goosey, K. O'Neill, S. Adhikari, and N. Ranabhat. 2015. Integrating targeted grazing in organic systems: Impacts on weed and ground beetle communities. 2015 American Society Annual Meeting. Symposium Management and Biological Control of Weeds in Agroecosystems. November 16-18, 2015. Minneapolis, MS.
9. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Gramig, G. and Carr, P. 2015. Weed seed predation dynamics in no-tilled and tilled organic wheat. *Proceedings of the Western Society of Weed Science* 68: 049.

2013/09 TO 2014/08 What was accomplished under these goals? Big Sandy, Montana. Crop rotation follows a flexible 5-yr cycle: Yr1 --safflower under-sown to sweet clover, Yr2 -- sweet clover cover crop, Yr3 -- winter wheat. Yr4 -- lentil, and Yr5 -- spring wheat. This study focuses on years 2, and 3 of the rotation. In 2014, paired plots were assigned to a) Grazed with sheep to terminate cover crops or b) Tilled under standard management. Grazing occurred twice during the growing season. Dickinson, North Dakota. The site consists of 75 plots arranged as a 3 x 5 factorial with each crop rotational phase and tillage combination replicated 5 times. Factors are tillage (clean-, reduced-, and no-till) and crop rotation phases 1) vetch-winter wheat, 2) winter wheat-cover crop, 3) proso millet-winter rye cover crop, 4) winter rye cover crop-dry bean, and 5) field pea-hairy vetch cover crop. 2014 was the 4th year of continual no-till in NT plots in wheat and pea plots. Fort Ellis Research Farm, Montana. Our experiment consists of 45, 0.2 ha plots under one of three management systems: 1. Organic with tillage, 2. Grazed organic, or 3. Conventional. Crop rotation at the site follows a 5-tr cycle. 1. Yr1 --safflower under-sown to sweet clover, Yr2 -- sweet clover cover crop, Yr3 -- winter wheat. Yr4 -- lentil, and Yr5 -- winter wheat. 1. Effects of targeted sheep grazing versus mechanical tillage on soil nutrients, compaction, erosion, and water availability At Big Sandy, we evaluated inorganic N (NH₄-N and NO₃-N) and potentially mineralizable N. Soil samples were collected from reduced-till sheep grazed plots and intensively tilled organic plots. Cores were collected from all plots and divided in 0-10, 10-20, 20-30 and 30-60 cm depth layers. Subsamples were removed and extracted with KCl. Extracts were then analyzed for inorganic NO₃-N and NH₄-N. A second subsample of the field moist soil was then removed in order to measure potential mineralizable N. Soil inorganic NO₃-N in the 0-10 and 10 cm depth layers was significantly lower in the grazed reduced-till plots compared to the intensively tilled plots. The differences indicate either mineralization of indigenous soil N was suppressed by reducing tillage, or that grazing of green manure leguminous crops removed N inputs from the system that lead to lower soil NO₃-

N. Soil NH₄-N levels were slightly higher in the grazed areas, but overall the results showed more plant available N (NO₃-N + NH₄-N) for the tilled systems. The anaerobic incubation test to estimate PMN showed no differences between the reduced till grazed plots and intensively tilled plots. At the Dickinson site, soil cores were collected this spring from the millet-rye rotation phase, separated into 0-10, 10-20, and 20-30 cm depth segments, and analyzed. Soil N pools (inorganic N and PMN) were generally not affected by cropping system management. Soil NO₃-N concentrations were greater in the no-till system but there was considerable variability across this field site and differences ($P < 0.05$) were observed.

2. Compare crop yield and quality between targeted sheep grazed no-tillage organic systems and tillage-based organic systems. In spring 2014, six 13 X 13m paired plots were randomly grazed or cultivated. In each plot, four 0.5m² frames were used to collect plant biomass by crop and weeds (weeds were separated into either dicot or grassy weeds) and to estimate field N budget. Samples were dried, weighed, and analyzed for N content. Subsequent samples were taken to capture crop or weed regrowth. We also assessed the 2014 safflower yield in plots that were either grazed or cultivated during the 2013 growing season.

3. Assess the top-down impacts of targeted sheep grazing on interactions between weeds, soil borne pathogens, insect pests, beneficial organisms, and crops. Big Sandy Weed community assessments. Weed cover, density, and number of flowers were counted within a 0.5m² frame placed every 0.5m along transects. Observations were conducted 4 times during the growing season. Insect community assessments. We placed a total of 36 total pollinators traps placed every 5m on the 55m transects. Carabid beetles were evaluated by placing 9 pitfall traps at each transect. Samples were obtained four times during the growing season. Insect-weed trophic interactions. Four times during the summer, we spent 20 minutes observing the weed flower visitors on each transect by walking slowly and recording if any insect was found on a blooming weed. We sampled insects through sweep netting. Disease incidence. Three times during the summer disease incidence was assessed by collecting five plants with roots. Disease incidence was recorded on the basis of symptoms in different parts of the plants. Data analysis and preliminary results. Species richness, abundance, diversity, cover, and flowering data will be used to correlate with insect and pathogen data collected to better understand these interaction networks.

Dickinson Sheep grazing. Mob grazing of no-till pea plots by sheep occurred during August and September, prior to seeding plots with hairy vetch and winter rye cover crops. Crop and weed community assessment. All crop, weed, ground beetle estimates were obtained as proposed. Hairy vetch has had significant winter kill in both 2013 and 2014, as has winter wheat. Therefore, spring wheat has been seeded into winter wheat plots in both 2013 and 2014 following soil warm-up. In addition to the very low wheat and pea yields under no-till systems when compared with conventional tilled one; millet and dry beans were a complete crop failure under no-till management.

4. Compare two lambing and two lamb finishing systems on lamb finishing performance, internal parasite infestations, carcass quality, and product shelf life. We continue assessing the lamb growth and carcass characteristics under 1) high energy - 60% barley, 2) moderate energy -70% alfalfa, 3) continuous graze, and 4) rotational graze. Body weight was recorded at the beginning and end of the finishing period after an overnight shrink without food or water. Fecal and blood samples were collected at 1) weaning, 2) beginning of the winter grazing period, and 3) beginning and end of the finishing period. Results indicated that while body weight and rib eye area did not differ between barley and alfalfa diets, it was significantly lower in both grazing treatments.

5. Develop enterprise budgets to assess economic trade-offs and impacts of integrating organic sheep and crop production in semiarid environments. Because cover crop represents high quality forage, they could provide \$24.00 - \$44.00 ha⁻¹ of direct revenue for producers as a grazing lease. Cash-crop yields do not differ between previously grazed and previously tilled systems, with preliminary results from this year indicating that winter wheat yields might be greater from the grazed organic compared to the tilled organic system. **PUBLICATIONS (not previously reported):** 2013/09 TO 2014/08

1. Type: Journal Articles Status: Accepted Year Published: 2014 Citation: Barroso, J., Z. Miller, E. Lehnhoff, P. Hatfield, and F. Menalled. Accepted with revisions. Impacts of cropping system and management practices on the assembly of weed communities. Weed Research. 2. Type: Journal Articles Status: Accepted Year Published: 2014 Citation: Miller, Z.; F. Menalled, U.M. Sainju, A.W. Lenssen, and P.G. Hatfield. In Press. Integrating sheep grazing into cereal-based crop rotations: Spring wheat yields and weed communities. Agronomy Journal. 3. Type: Journal Articles Status: Submitted Year Published: 2014 Citation: Goosey, H.B, S. C. McKenzie, M. G. Rolson, K. M. O'Neill, and F. Menalled. Submitted. Impacts of contrasting alfalfa (*Medicago sativa*) production systems on the drivers of carabid beetle (Coleoptera: Carabidae) community dynamics. Environmental Entomology. 4. Type: Journal Articles Status: Submitted Year Published: 2014 Citation: McKenzie, S., H. Goosey, K. M. O'Neill, and F. Menalled. Submitted. Integrating livestock for cover crop termination in horticultural vegetable production: Impacts on weed and ground beetle (Coleoptera: carabidae) communities. Agriculture, Ecosystems and Environment. 5. Type: Journal Articles Status: Submitted Year Published: 2014 Citation: McKenzie, S., H. Goosey, K. M. O'Neill, and F. Menalled. Submitted. Integration of sheep grazing for cover crop termination into market gardens: Agronomic consequences of an ecologically-based management strategy. Soil and Tillage Research. 6. Type: Journal Articles Status: Awaiting Publication Year Published: 2014 Citation: Miller, Z. and F. Menalled. In Press. Impact of species identity on biologically-mediated plant-soil feedbacks in a low and a high intensity agroecosystems. Plant and Soil 7. Type: Conference Papers and Presentations Status: Published Year

Published: 2014 Citation: Johnson, S., P.R. Miller, F. Menalled, and Z. Miller. 2014. Reducing tillage on organic dryland farms in the Northern Great Plains with grazers. Agronomy Society of America Annual Meeting. Long Beach CA November 3, 2014 8. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Adhikari, S. F.D. Menalled, L. Burkle, K. O'Neill, and D.K. Weaver. 2014. Impacts of farming management system on carabid beetle community in Northern Great Plain dry land agroecosystems. Western Society of Crop Science Annual Meeting. Bozeman, MT. July 8-9, 2014. 9. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: McKenzie S.C., H. Goosey, H., K. O'Neill, and F. Menalled. 2014. Effects of sheep grazing for cover crop termination on plant community structure, weed pressure and crop yields: evaluating an ecological-based management strategy for agroecosystems. Joint Canadian Weed Science Society - Weed Science Society of America Annual Meeting. Vancouver, BC, Canada. February 4, 2014.

2012/09 TO 2013/08 What was accomplished under these goals? Big Sandy, Montana. Six 13 x 13m paired plots were established in a cover crop field and assigned to a) grazed with sheep to terminate cover crops or b) tilled under standard management Dickinson, North Dakota. The site consists of 75 plots arranged as a 3 x 5 factorial with each crop rotational phase and tillage combination replicated 5 times. Factors are tillage (clean-, reduced-, and no-till) and crop rotation phases (1) vetch-winter wheat, 2) winter wheat-cover crop, 3) proso millet-winter rye cover crop, 4) winter rye cover crop-dry bean, and 5) field pea-hairy vetch cover crop). Fort Ellis Research Farm, Montana. The site consists of 45 plots and sweet clover cover crop plots were grazed. Towne's Harvest Farm, Montana. In this commercial vegetable farm, every year 1/6 is planted to a cover crop mixture. Cover crops were terminated either mechanically or through sheep grazing. The remaining 5/6 of the farm is planted to diverse fresh vegetables. Methods and Preliminary Results 1. Effects of targeted sheep grazing versus mechanical tillage on soil nutrients, compaction, erosion, and water availability. Soil cores were collected this spring from the millet-rye rotation phase at the Dickinson site, separated into 0-10, 10-20, and 20-30 cm depth segments, and analyzed. Soil N pools (inorganic N and PMN) were generally not affected by cropping system management. Soil NO₃-N concentrations were greater in the no-till system but there was considerable variability across this field site and differences ($P < 0.05$) were observed. Soils cores were collected at the Big Sandy site in April 2013 and separated into 0-10, 10-20, 20-30, and 30-60 cm depth. 2. Compare crop yield and quality between targeted sheep grazed no-tillage organic systems and tillage-based organic systems. Six 13 X 13m paired plots were randomly placed on an organic pea field and either grazed by sheep or cultivated. Four 0.5m² frames were used on each plot to obtain plant biomass by crop and weeds (weeds were separated into either dicot or grassy weeds) and to estimate field N budget. Samples were dried, weighed, and analyzed for N content. Subsequent samples were taken to capture crop or weed regrowth. In 2014 spring wheat yield will be assessed. 3. Assess the top-down impacts of targeted sheep grazing on interactions between weeds, soil borne pathogens, insect pests, beneficial organisms, and crops. Big Sandy, Montana. Weed community assessments. Weed cover, density, and number of flowers were counted within a 0.5m² frame placed every 0.5m along transects. Observations were conducted 4 times during the growing season. Insect community assessments. We assessed pollinators, carabid beetles, and wheat stem sawflies. We placed a total of 36 total pollinators traps placed every 5m on the 55m transects. Carabid beetles were evaluated by placing 9 pitfall traps at each transect. Samples were obtained four times during the growing season. Wheat stem sawfly abundance was estimated prior to wheat harvest. Insect-weed trophic interactions. Four times during the summer, we spent 20 minutes observing the weed flower visitors on each transect by walking slowly and recording if any insect was found on a blooming weed. We sampled insects through sweep netting. Disease incidence. Three times during the summer disease incidence was assessed by collecting five plants with roots. Disease incidence was recorded on the basis of symptoms in different parts of the plants. Data analysis and preliminary results. Species richness, abundance, diversity, cover, and flowering data will be used to correlate with insect and pathogen data collected to better understand these interaction networks. Dickinson, North Dakota Sheep grazing. Mob grazing of no-till pea plots by sheep occurred during August and September, prior to seeding plots with hairy vetch and winter rye cover crops. Sheep density was insufficient so supplemental mowing also was done. Hairy vetch was seeded into conventional-till and reduced-till pea plots after grain harvest and seedbed preparation was completed on 27 August. Likewise, a 4-way cover crop mixture was seeded into wheat plots on that same date. The cover crop mixture was grazed in no-till plots prior to the killing of cover crop plants by freezing temperatures (mid- to late-October). Crop and weed community assessment. Lack of competition coupled with abundant early spring moisture, created ideal conditions for establishment of weeds in no-till plots. Complete crop failure occurred in no-till millet plots and is likely in no-till navy bean plots. Grain yield in no-till wheat plots was 45% lower (32 bu/ac) than in conventional-till wheat plots (58 bu/ac), and 63% lower in no-till pea plots (10 bu/ac) than conventional-till pea plots (27 bu/ac). Fort Ellis Research Farm, Montana. Weed community assessment. In each plot 20 0.5m² frames were used to assess weed cover and density. At peak biomass for each crop two destructive samples were taken from each quadrant and plants were separated by species. Samples were dried and weighed, and analyzed for N content. In the lentil and wheat plots, two 3.5 x 1.5m areas were established. On one half of each of these plots, the crops were hand-weeded and the other half was left untouched to assess the impact of weeds on yield. A yield strip

was harvested from the center of the lentil and winter wheat plots using a combine. Protein, moisture, and test weight data were also taken. Data will be analyzed with the above weed data to understand crop-weed dynamics. Insect community assessment. 72 pitfall traps were established in in the tilled organic, grazed organic, and no-till winter wheat and winter peas crops. Samples were taken every 3 weeks between June and September 2013. Results suggest that we failed to observe any difference in the activity density and species richness of beetles across management systems but a small fraction of the sample has been analyzed. Disease incidence. A total of 27 winter wheat and lentils plots were selected. Three times during the growing season five plants with roots were obtained and disease incidence was recorded. Towne's Harvest Farm, Bozeman, Montana Plant community assessment. We collected aboveground plant biomass once prior to cover crop termination and once after cover crop termination, but prior to fall senescence, by placing four 0.44 m by 0.76 m quadrats per plot and assessing dry biomass per species during the first year. Results indicate that both methods used to terminate the cover crop equally reduced plant biomass. Insect community assessment. To monitor carabid beetle communities, we used pitfall-trapping. We collected pitfall traps weekly during the growing season and identify all carabid beetles to species. Metrics for carabid community structure include species richness, activity-density, and species diversity. A preliminary inspection of our results indicates that the approach used to terminate the cover crop similarly impacted beetles communities and activity density. 4. Compare two lambing and two lamb finishing systems on lamb finishing performance, internal parasite infestations, carcass quality, and product shelf life. We compared finishing performance, carcass characteristics, shelf life, and shear values of meat from 15-mo-old wethers born in May and finished in drylot or finished on cover crops. Body weight (BW) was recorded at the beginning and end of the finishing period after an overnight shrink without food or water. Final BW, average daily gain along with ADG and feed to gain ratio (F:G) were evaluated. After finishing, lambs were slaughter and carcass weight, 12th rib backfat thickness and loineye area was determined. Fecal and blood samples were collected at 1) weaning, 2) beginning of the winter grazing period, and 3) beginning and end of the finishing period to measure parasite load. **PUBLICATIONS (not previously reported):** 2012/09 TO 2013/08 1. Type: Conference Papers and Presentations Status: Published Year Published: 2013 Citation: Mckenzie, S., H. Goosey, K. O'Neill and, F. Menalled. 2013. What is the effect of sheep grazing for cover-crop termination on associated biodiversity? Western Section ASAS Annual Meeting. June 19-21, 2013. Bozeman, Montana 2. Type: Conference Papers and Presentations Status: Published Year Published: 2013 Citation: McKenzie, S., H. Goosey, K. O'Neill, and F. Menalled. 2013. Impact of cover crop termination through sheep grazing on weed community structure. 2013 Western Society of Weed Science Meeting. March 11-14, 2013. San Diego, CA 3. Type: Conference Papers and Presentations Status: Published Year Published: 2013 Citation: McKenzie, S., H. Goosey, K. O'Neill, and F. Menalled. 2012. Does terminating a cover crop with sheep grazing change plant community structure? Poster session, Annual Meeting of the Montana Chapter Society for Conservation Biology. October 24-26, Bozeman, MT.

[↑ Return to Index](#)

Whole-farm Organic Management of Bmsb and Endemic Pentatomids Through Behaviorally-based Habitat Manipulation

Accession No.	0230933
Subfile	CRIS
Project No.	NJ08931
Agency	NIFA NJ.
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2012-51300-20097
Proposal No.	2012-02222
Start Date	01 SEP 2012
Term Date	31 AUG 2015
Grant Amount	\$2,672,327
Grant Year	2012
Investigator(s)	Nielsen, A.; Bessin, R.; Dively, G.; Grieshop, M.; Hamilton, G. C.; Hoelmer, K. A.; Hooks, C. R.; Kotcon, J.; Leskey, T.; Matthews, C.; Mizell, R.; Park, Y. L.
Performing Institution	Entomology, RUTGERS, THE STATE UNIVERSITY OF NEW JERSEY, 3 RUTGERS PLZA

NON-TECHNICAL SUMMARY

This integrated project utilizes a multi-regional, transdisciplinary approach for the development and dissemination of whole-farm organic management for the brown marmorated stink bug (BMSB). It is the direct result of a 2011 USDA-OREI planning project. BMSB is an invasive insect causing severe economic loss in Mid-Atlantic States, with damage increasing in Southern states. It is an especially devastating pest for organic farmers. Current organic management tactics have not mitigated damage because BMSB is highly mobile, feeds on a diverse number of crops and occupies a large geographic area. Thus, whole-farm management is required for effective organic control. This will aid growers in the selection and planning of trap crops, enhancing natural enemies and cultural control, all of which will be researched in this project. We will investigate the cues and capacity for dispersal and identify movement patterns that will be integrated into development and execution of proactive stink bug management. We will partner with eOrganic to aid in the novel dissemination of research findings, which will be supplemented with annual on-farm demonstrations and social media. This project directly addresses OREI goals 1 and 6 as BMSB represents a major threat to organic production across many commodities. Our project has the support or involvement of 25 researchers, 3 organic organizations, and 12 organic farmers and will have national impact. Seven farmer-stakeholders have been fully engaged in the development of this proposal and will continue to play an integral role in research and outreach activities. ****OBJECTIVES:**** The long-term goal of our project is to develop and deliver sustainable, whole-farm management programs for the brown marmorated stink bug (BMSB), (Hemiptera: Pentatomidae, *Halyomorpha halys*), and endemic pentatomids, that are true to the legal definition and ethos of organic agriculture. BMSB has rapidly become a devastating pest of conventional and organic agriculture in Southern and Mid-Atlantic regions and is expanding to surrounding states. Management of this pest with conventional/synthetic insecticides has proven extremely challenging and there are currently no viable organic management tactics. The programs developed in our project will be based on BMSB dispersal and whole-farm movement integrated with core organic pest management strategies, i.e. conservation biological control, habitat manipulation and the use of trap crops and crop barriers. Our specific objectives are: 1. Develop habitat manipulation tactics based upon how host plant phenology impacts BMSB preference and dispersal. 2. Determine biotic and abiotic factors affecting adult and juvenile BMSB whole-farm movement. 3.

Determine the identity and importance of extant natural enemies of stink bugs and their impact on BMSB populations. 4. Evaluate integrated management plans for BMSB and endemic stink bugs specific to organic production systems. 5. Develop and deliver extension materials for organic growers. Outputs: The primary research output will be the relative efficacy of integrated, whole-farm tactics opposed to single pest management tactics for BMSB. We will establish dispersal behaviors and whole-farm movement patterns of adult and nymph BMSB to identify the spatial scale and sequence in which BMSB interacts with the landscape to develop management strategies. In addition, we will field-test pest management systems such as trap crops, row covers, insectary strips and enhancing natural enemies as the best integrated organic management practices for BMSB. Select grower sites will also serve as integrated farms to further evaluate project impact. Data collected and feedback received from the integrated farms will be used in final preparation of outreach material. We aim to strengthen partnerships with organic growers by providing a diverse set of educational opportunities that increase grower understanding of BMSB behavior and ecology and initiate the use of whole-farm habitat manipulation strategies developed by this project. Outreach for organic management of BMSB will occur in four primary ways: 1) web-based materials 2) on-farm demonstrations, instructional clinics, and field days 3) education materials through eOrganic and 4) traditional extension materials.

APPROACH

Objective 1) Develop habitat manipulation tactics based upon how host plant phenology impacts BMSB preference and dispersal. We will identify the most suitable trap crop for BMSB based on density and temporal susceptibility to BMSB through a Latin-square design. Two trap crops will be further evaluated for their management potential to protect select vegetable and field crops and we will compare management strategies within the trap crop. Finally, the whole-farm movement patterns by BMSB between trap and cash crops will be studied using ELIS based methods. Objective 2) Determine biotic and abiotic factors affecting adult and juvenile BMSB whole-farm movement. Through whole-farm sampling at multiple sites, we will establish spatiotemporal distribution patterns and relationships of BMSB within individual farms to crops, structures and non-host plants. We will also determine the abiotic and biotic factors affecting BMSB adult flight behavior using flight mills and flight tunnels and conduct two mark-release-recapture experiments with nymphs to elucidate their spatial scale of movement and host preferences. To reduce the population pressure in future years, overwintering site selection within human-made structures will be investigated. Specifically, we will characterize commonalities of human-made structures to develop a predictive model identifying sites most likely to host BMSB overwintering populations and develop an overwintering trap incorporating those characteristics. Objective 3) Determine the identity and importance of extant natural enemies of stink bugs and their impact on BMSB populations. We will conduct region-wide surveys to identify the species composition and rates of egg parasitism and predation for BMSB and endemic stink bugs in candidate trap crops and a wide range of organic cash crops. A subset of sentinel BMSB eggs will be monitored using day/night vision cameras to quantify predator species rates. The incorporation of insectary plants to enhance natural enemies, specifically egg parasitoids, in field corn and vegetables will be investigated. Due to the use of non-synthetic insecticides on organic farms, the impact of these applications to natural enemies will be assessed at both individual species and at the broader community level. Objective 4) Evaluate integrated management plans for BMSB and endemic stink bugs specific to organic production systems. We will determine the efficacy and limitations of barrier fabrics as cultural control tactics by comparing row cover materials and the impact on natural enemy populations in peppers. In the final project year, together with eOrganic, 5 cooperating growers will integrate the management tactics describe in the above objectives and evaluate successful management tactics for BMSB. All data will be analyzed with either ANOVA or t-tests with each farm as a blocking factor. Objective 5) Extension and Outreach. Outreach for organic management of BMSB will occur in four primary ways: web-based materials, on-farm demonstrations, eOrganic materials and traditional extension materials.

PROGRESS

2012/09 TO 2017/08 Target Audience: The target audience for the final project year remained growers who wish to manage brown marmorated stink bug using organic methods. Much of the activity within this final year was writing scientific manuscripts to disseminate findings to the scientific community. Our social media outlet, via the Facebook page, remained live, although not very active. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? The project has trained 6 graduate students (1 PhD, 5 MS) on organic management of invasive species with a special focus on biological control. Additionally, training for 5 post-doctoral research associates on insect dispersal, management, and biological control was conducted during the course of this project. Both students and postdocs had multiple opportunities to share their research findings with communities of interest and form research collaborations with

the broader group. Many were involved in our annual planning meetings, quarterly phone calls, and provided feedback on experimental design and data as it was being collected. Over 30 undergraduate students have been trained on insect colony maintenance, survey and monitoring techniques, insect identification, and organic management. How have the results been disseminated to communities of interest? The results have been transferred to organic farmers and the general public. We used social media to engage a broad audience through the development of a Facebook page ("Organic Management of BMSB"), two webinars hosted by eOrganic including a YouTube video of the webinar. The webinars have been viewed in total over 1000 times and were originally attended by homeowners, extension educators, and farmers. Findings from this project have been discussed at multiple extension meetings within the US, reaching an audience of both conventional and organic growers. Field days hosted by Universities or participating organic growers reached hundreds of farmers, homeowners, and extension educators annually. Much of the project findings are applicable at multiple scales and management approaches. Due to the overwintering behavior of this pest species, a citizen science project was created that engaged homeowners in the Washington DC area to count stink bugs on their houses in September and October. Over 100 homeowners participated with usable data and from this, we were able to identify commonalities in houses and landscape features that have the highest number of BMSB aggregation. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported

2013/09 TO 2014/08 Target Audience: The research collaborators have reached a broad audience through various outputs during the first year of this OREI project to develop behaviorally-based methods to organically manage stink bugs. Through the utilization of demonstration field days, we targeted organic farmers of many agronomic, vegetable, and fruit crops, as well as extension personnel and consumers. We also publicized our work through numerous local news and online programs to inform the general public on the importance of stink bug research and management. Changes/Problems: Nationally, populations of BMSB were lower than anticipated in 2014. The cool wet spring also delayed planting of many trials and also mitigated BMSB populations. Although populations eventually increased in late season, this emphasizes the need to repeat field trials in 2015. Obj 1: Trap crop on-farm trials at select sites will utilize a management tactic, specifically baited pheromone traps to develop a 'pull-pull' system. Obj 2: No changes Obj 3: Based on preliminary results of the benefits of insectary plants for enhancing natural enemies, we have added a wildflower comparison trial to evaluate different perennial native wildflowers at increasing natural enemy services for BMSB. Because generalist predators appear to have a greater impact on BMSB eggs than parasitoids, we will survey the predator community and screen for the presence of BMSB DNA. Instead of focusing video on egg mass predation, in NJ we will change to observing predator interactions with 1st instar BMSB. We are currently conducting detailed observations on the impacts of predators to egg masses which will be a central part of a factsheet and video output developed. Obj 4: The integration of multiple tactics will occur slightly differently than previously imagined. In our final project year, we now understand the dispersal capacity and behaviors of BMSB nymphs, including 'hot spots' on organic farms. This will allow recommendations to be made on placement of high risk crops and trap crops. Integration practices will recommend the use of exclusion netting on high valued crops and the use of insectary plantings in preferred oviposition sites. What opportunities for training and professional development has the project provided? To date this project has helped support the training of 6 post-doctoral researchers, 12 graduate students and 15 undergraduate student interns. Project members have provided training to over 240 master gardeners. The USDA conducted a parasitoid identification workshop to identify key characteristics of native species. The 'Great Stink Bug Count' trained over 200 participants in 2013 and 2014 on identification of BMSB and is being utilized to identify key characteristics of houses that serve as overwintering structures for BMSB. Additionally, research results have been communicated to researchers at regional and national meetings. How have the results been disseminated to communities of interest? The results of our project as well as basic biology and identification of BMSB have been disseminated widely to communities of interest in 11 states throughout the country. We have also worked directly with over 10 organic growers in these states by conducting research at their establishments. In Tennessee over 60 stakeholder were reached at field days. In Maryland, at field days and openhouses over 125 individuals were taught about trap cropping methods and insectary plants. Over 100 seed packets of partridge pea were given to interested farmers who wanted to try insectary plantings to increase natural enemy activity on their own farm. In NJ, approximately 25 organic growers attended an organic community meeting where BMSB biology, trap crop methods were discussed and handouts of project results were distributed. Another 80 small farm and sustainable growers attended a workshop to learn about BMSB biology, trap cropping and insectary plants. Rodale demonstrated the trap cropping field experiment to over 200 visitors. In Kentucky, over 400 farmers attended workshops and field days where information on BMSB biology and exclusion netting was demonstrated. In North Carolina a series of workshops trained 145 extension personnel and farmers on BMSB biology and natural enemies. A webinar presented by project director A. Nielsen has had 463+ views on YouTube highlighting BMSB biology and relevant information for organic producers. What do you plan to do during the next reporting period to accomplish the goals? Obj 1 Trap cropping - In 2014 we conducted trap cropping trials at 11 sites at cooperating grower farms or research farms. Preliminary data looks promising

but suggests that a killing agent may be needed under high population pressure. In year 2 we will continue the same project, potentially with the addition of a killing agent. Obj 2 Dispersal behavior - Whole-farm movement on-farm studies will be continued. Host plant volatiles that may contribute to nymphal host plant selection will be analyzed. Results from 2014 Great Stink Bug Count will be tabulated and analyzed. Obj 3 Natural Enemies - Surveys of egg mass predation and parasitism will continue. Molecular markers for identify of BMSB predators will be completed. Impact of insecticides on natural enemies will be conducted for a second year. Obj 4 Integration - Exclusion netting experiments are completed. The integration of key tactics such as trap cropping, insectary plantings and trap crop management, nymphal dispersal behavior will be combined at selected farm sties. Obj 5 Extension and Outreach - In the final project year, we will develop and publish webinars, videos, factsheets on BMSB dispersal behavior, organic insecticides, trap cropping methods and impact by natural enemies.

2012/09 TO 2013/08 Target Audience: The research collaborators have reached a broad audience through various outputs during the first year of this OREI project to develop behaviorally-based methods to organically manage stink bugs. Through the utilization of demonstration field days, we targeted organic farmers of many agronomic, vegetable, and fruit crops, as well as extension personnel and consumers. We also publicized our work through numerous local news and online programs to inform the general public on the importance of stink bug research and management. Changes/Problems: Under sub-objective 2d, "Determine characteristics of human-made structures that serve as attractive BMSB overwintering habitat," we have initiated a new Citizen Science project aimed at identifying the cues used by BMSB to select overwintering sites. This additional project will increase the size of our sampling ability by utilizing citizen volunteers to count the number of stink bugs on their houses every day between September 15 and October 15 and filling out a form to fill out with a description of his or her house, surrounding vegetation, and a rough drawing of where the home is located. Having hundreds of volunteers will help us to determine if factors like the color, shape, size, vegetation around the house, and elevation play a role in where BMSB overwinter. Under sub-objective 2b, "Determine the abiotic and biotic factors affecting BMSB adult flight behavior," we have postponed flight mill studies at one of our two proposed research sites. The other site will continue with flight mill studies as planned. The first site will instead increase their focus on in-lab trials of BMSB nymph dispersal and behavior as part of sub-objective 2c, "Determine factors affecting BMSB nymphal dispersal behavior." This additional dispersal and behavior work will be used to support our field research on nymphal dispersal. What opportunities for training and professional development has the project provided? Several post-doctoral research associates, graduate and undergraduate students (including students whose PhD dissertations or masters theses will result from this work), and growers were instrumental in accomplishing this research. In order for these participants to skillfully their portions of the work, they were initially trained by the investigators at their corresponding institutions. Training consisted of brown marmorated stink bug (BMSB) identification, an introduction to the overall OREI project, and education on performing and completing appropriate portions of the project. During the first year of this OREI funded project, for example, at Rutgers University a post-doctoral research associate, Brett Blaauw, a PhD student, John Pote, and two research assistants were trained to work on the OREI project. The USDA-ARS in West Virginia trained one post-doctoral research associate, Doo-Hyung Lee, a masters student from Virginia Tech, Torri Hancock, and an undergraduate research assistant. In Delaware, the USDA-ARS trained Christine Diekhoff, a post-doctoral research associate, and a research assistant was trained at the University of Delaware to work on the OREI funded project. Additionally, the University of Maryland trained three graduate students, a post-doctoral research fellow, two research associates, two grade school teachers, and several student research assistants. Jenny Moore, a post-doctoral research associate and one student research assistant were trained at the University of Tennessee. The University of Florida had one student research assistant, North Carolina State University trained Rachel Suits, a post-doctoral research associate, and two undergraduate research assistants, and the Rodale Institute trained two research assistants. Furthermore, two grower collaborators, Haroun Hallack of Redbud Farms and Warren Landis of Strawberry Creek Farms were also trained in BMSB identification and execution of research projects at their respective farms. The training these individuals received was essential for the completion of the first year objectives from this OREI project. The education and experience everyone received while participating during this first year is also important for their advancement in their career and/or development as future scientists. How have the results been disseminated to communities of interest? Preliminary results based on Year 1 activities have been distributed to target audiences, primarily organic farmers, through an online webinar and farm field days. We have found that there is still a lot of confusion among farmers regarding identification of this species. Because of differences in management tactics and injury from native stink bugs, may extension efforts concentrated on identification. A webinar was presented by PD Nielsen and hosted through eOrganic (posted at <http://eorganic.info/brown-marmorated-stink-bug-organic>), which discussed a background of BMSB biology and how the project aims to investigate management in organic systems in February 2012. During the webinar there were 135 participants and the You-Tube video has received 326 views since it's posting. In addition, there were numerous newspaper articles that discuss various aspects of the project. Three sites specifically participated in field days where aspects of our research were demonstrated. University of Maryland (UMD) held a field day at

the Clarksville, MD experiment station with 4,000 attendees. During this PI's Hooks and Dively had two posters -- one on habitat manipulation to increase natural enemies of stink bugs and the other on how to use flowering borders to enhance biological control of stink bugs in organic field corn. UMD also participated in three twilight meetings where similar research on conservation biological control was presented to 65, 45, and 30 attendees on August 2, 9, and 28th respectively. West Virginia University hosted a field day at the student organic farm where PI's Park and Kotcon showed 30 attendees how to identify and control BMSB along with explaining about the multistate OREI project in general. University of Tennessee, which is on the edge of BMSB distribution, participated in an organic crops field tour where PI Rogers discussed damaged and organic management options for BMSB and native stink bugs in April. Dr. Rogers also gave a workshop on BMSB at the University of Tennessee organic and sustainable crop production series in September. The Rodale Institute held an annual field day during which PI Zinati spoke about BMSB and trap crops to 80 people who also received a brochure on identification. Ohio State University PI Welty also presented about stink bug management at 6 field days over the summer of 2013. Three states conducted research trials on university run student organic farms at West Virginia University, University of Tennessee, and Michigan State University. Collaborating with the student groups allows us to reach a much larger group of students who are learning the ins and outs of organic farming practices and will be able to incorporate such tactics into their own farms during internships and when they run their own farm in the future. Most importantly though has been our work with the cooperating growers on this project. Many of these experiments were conducted on organic farms, including Muth Family Farm (NJ), Terhune Orchards (NJ), Rodale Institute (PA), Redbud Farm (WV), Strawberry Creek Farm (VA), Gladheart Farms (NC), Thatchmore Farms (NC), Brickel Creek Organic Farm (OH), Northridge Organic Farm (OH), Stratford Ecological Center (OH), and Three Brothers Orchards (MI), where we were able to communicate results directly to the stakeholders. What do you plan to do during the next reporting period to accomplish the goals? During the second year of this project we plan to increase our emphasis on Objective 4: Extension and Outreach. With data from our first year of research having been analyzed, we are now going to disseminate our results to organic growers and the general public through printed and online extension materials, grower meetings, and various research presentations. The printed and online extension materials will be supplemented with activities from our resources with eOrganic, such as informational videos and webinars on trap cropping and crop barriers, which will be posted on our project website (<http://eorganic.info/brown-marmorated-stink-bug-organic>). Grower meetings will consist of field days during the spring with on-farm demonstrations to show research in action and to illustrate organic management techniques for BMSB to growers. These meetings will take place at our research sites, such as Strawberry Creek, Redbud Farm, and at the Rodale Institute. Furthermore, research presentations to reach our extended science community will be given at various meetings across the country, such as the Entomological Society of America's Annual Meeting. In addition to disseminating results from our first year, the second year of this project will also focus on the continuation and starting of research projects. For example, as part of Objective 1, Redbud Farm, Rodale Institute, and University of Maryland will continue their work investigating the temporal susceptibility of trap crops to BMSB. This coming year will be the starting year for three other projects. A large, multi-state project to determine BMSB spatial and temporal utilization patterns of trap and cash crops will be conducted at Redbud Farm, West Virginia University, Rutgers University, Rodale Institute, University of Maryland, Virginia Tech, The Ohio State University, North Carolina State University, and University of Tennessee. A smaller-scaled project to determine the source-sink dynamics of the trap crop within the whole farm will be carried out by researchers at Rutgers University and Redbud Farm. Additionally, as part of Objective 1, Rutgers University will investigate management techniques for BMSB within trap crops. Projects associated with Objective 2 are all continuations from the first year of research. For instance, researchers at West Virginia University, Rutgers University, and Redbud Farm will continue during this second year to assess patterns of BMSB within-farm movement. Also, project team members from Rutgers University and USDA-ARS in Virginia will continue to investigate the abiotic and biotic factors affecting BMSB adult flight behavior as well as the factors affecting BMSB nymphal dispersal behavior. As a multi-state project, Rodale Institute, University of Florida, USDA-ARS Virginia, and Rutgers University will carry on an investigation into an optimal overwintering trap for BMSB and researchers at the USDA-ARS in Virginia will continue to work on a project to determine the characteristics of human made structures that serve as attractive BMSB overwintering habitat. Determining the identity and importance of natural enemies of stink bugs is the key component of Objective 3, and as part of this objective we will be focusing on the continuation and starting of new research projects to address this issue. Continuing a large, multi-state project from our first year, project team members from Rutgers University, West Virginia University, Virginia Tech, University of Maryland, USDA-ARS Newark, University of Kentucky, North Carolina State University, The Ohio State University, University of Tennessee, and Michigan State University will be investigating species composition of parasitoids and predators, as well as the rates of egg parasitism and predation for native and invasive sting bug herbivores. Also as a continuation from our previous year, a project to investigate the potential of insectary plants to enhance BMSB and native pentatomid predation/parasitism will be conducted by researchers at the University of Maryland and The Ohio State University. As a new project for year two, the University of Maryland, Redbud Farm, USDA-ARS Newark, The Ohio State University, North Carolina State

University, and Rutgers University will assess the impacts of trap crops on natural enemies of BMSB and native pentatomids. Another new project, as part of Objective 3, is to determine natural enemy mortality due to organic insecticides, which will be carried out by researchers at the University of Maryland, North Carolina State University, West Virginia University, and USDA-ARS Newark. Additionally, early in January 2014 the project team will meet with the advisory panel: Shearer, Cullen, Tooker, Koan, and Schonbeck. This meeting will allow the researchers to receive feedback from the panel on their thoughts and concerns about the status of the OREI project. By meeting with them early in the year, any advice or suggestions that they may have can then be used to modify our project plans for the rest of the year. In conjunction with the advisory panel meeting, the project team will also meet in early January 2014 for a project planning meeting to make sure everyone is up-to-date on the status of the project and to make sure everyone is ready for the second year of this project. Furthermore, the project team will continue to participate in monthly conference calls to answer any questions people may have and to keep everyone up-to-date on the project.

IMPACT

2012/09 TO 2017/08 What was accomplished under these goals? This project has trained 6 graduate students and 5 postdocs in entomology, specifically on the behavior, biological control, and organic management of an invasive agricultural pest. Our work has resulted in 11+ peer-reviewed scientific publications. Key project findings are the development of a trap crop system for brown marmorated stink bug (BMSB) and identification of predator taxa that are feeding on BMSB within organic farms. We have been able to identify how BMSB moves within an organic farm landscape, how they select host plants, and finally characteristics of overwintering sites. This project was a collaborative effort by Universities, the USDA, and organic farmers. Through our work, we have educated hundreds of farmers annually through our extension efforts within the mid-West and Eastern US on organic management tools that can be adopted broadly. Our specific objective accomplishments are below: Develop habitat manipulation tactics for stink bugs: Multi-state testing in 2013 identified grain sorghum and sunflower as preferred plant species that attract stink bugs and could be used as a management tool. On 7 commercial organic farms and 3 University experiment stations we evaluated a polyculture of sunflower and sorghum trap crop surrounding organic peppers in 2014-2015. We assess insect numbers and injury on peppers weekly. The trap crop significantly reduced minor stink bug injury, but not major (>2 feeding sites/fruit). Retention and/or mortality of an insect within the trap crop increase its success. Incorporation of traps baited with the BMSB aggregation pheromone did not further reduce injury to peppers. However, evaluations of the dispersal between trap crop and peppers through harmonic radar and protein marking showed that minimal movement occurs between the trap crops to the peppers. The trap crop is able to retain BMSB for at least 7 days but management within the trap crop would be needed to reduce injury to acceptable levels. Whole-farm movement: In two experiments we identified that BMSB nymphs (immatures) move at a rate of 2 m/hr. Further, we used mark-release-recapture methods to identify that BMSB nymphs make feeding choices and disperse to a more suitable crop depending on ripening. We have further collected, analyzed, and evaluated host plant volatiles emitted from these crops as well as peach and apple to investigate specific cues that are used by BMSB. Laboratory experiments confirm that a blend of volatiles was most attractive to nymphs. These manipulative experiments were further validated by large-scale sampling to look at the sequence of crop use and hot spots within organic farms. Hot spots occurred within ornamental and fruit trees, typically in the family Rosacea, but also showed an edge effect along wooded edges, and areas with the highest number of BMSB shifted depending on ripening of the crop. The overwintering behavior of BMSB was investigated in western MD. Research focused on the pre, during and post mass-flight behavior of BMSB. A trap was developed that can mass trap BMSB on buildings. A citizen science project engaged homeowners to collect data on characteristics of overwintering structures used by BMSB. In 2013 and 2014, roughly 150 data sets were collected from participants who counted BMSB on their homes and results suggest brown homes situated in agricultural and woodland dominated landscapes have the highest populations of overwintering BMSB. Determine natural enemies of BMSB: A multi-state survey identified that native egg parasitoids had minimal impact (<1% parasitism) in organic systems. Surveys on organic farms did not find the Asian parasitoid of BMSB, *Trissolcus japonicus*. Generalist predators caused 10-15% egg mortality in organic farms. A photographic library that defined predator feeding damage categories was compiled to assist with identifying key predators attacking BMSB eggs in the field. Laboratory studies showed that predators exhibit life-stage preferences with taxa such as grasshoppers and damsel bugs feeding on eggs and nymphs, respectively. This indicates that natural enemy impacts are underestimated through sentinel egg mass surveys. We developed a protocol for detecting small amounts of BMSB DNA using molecular gut content analysis. This allows descriptive assessments of predator identity and feeding rates under field conditions. Fourteen percent of field collected predators in NJ tested positive for BMSB DNA and suggests that the predatory insects fed on BMSB within the last 48h. This is higher than would be expected for predators who are not co-evolved and suggests that

predators may play an important role on organic farms for managing BMSB. Most of the positive predators were found in soybean, which is also highly attractive to BMSB. Insectary plantings were evaluated to increase natural enemy response to BMSB. In MD and OH, partridge pea was studied in organic field corn and blackberry plantings. Overall there was a high rate of parasitism and predation of all stink bug eggs assessed, but the impact of natural enemies on BMSB was not enhanced through the addition of partridge pea. In NJ, parasitism and predation within perennial wildflower plots were assessed. Despite an overall increase in the natural enemy community in the wildflower plots and higher predation due to piercing- sucking predators, there was no difference in chewing predation or parasitism between the control and wildflower plots. Evaluate organic management options for BMSB: Mechanical exclusion of stink bugs was studied using various sizes of mesh netting over organic bell peppers. Laboratory studies indicated that netting smaller than 1/4" was needed to impede adult BMSB movement. Field studies evaluated sizes of 1/6", 1/8", and 1 mm mesh as a full season management tactic. Measurements on yield, stink bug injury, and natural enemy populations were made. There was a correlation between netting size and the proportion of the stink bug injury and all netting sizes reduced damage compared to the open controls. However, the finest mesh cages had secondary outbreaks of aphids due to exclusion of natural enemies. Field trials on pepper and tomato evaluated the efficacy and rate of organic insecticides for control of stink bugs. BMSB was the most predominant species in pepper, and the most effective treatments included Veratran D at 15 lbs/acre (93% control of adults) and Azera at 56 oz/acre (68%). Compost tea also causes egg mortality. Insecticides, such as Entrust, were found to cause high mortality against native egg parasitoid species. Develop and deliver extension A Facebook community page, BMSB in Organic Farming Systems, has 156 followers from 10 different countries. The Facebook page was created to inform and update growers and the public on the status and results from this project. Two webinars hosted by eOrganic were delivered to homeowners, farmers, and extension educators on BMSB biology and biological control. The webinars were each attended by ca. 125 people and the associated YouTube videos have been viewed 1000 times. Factsheets discussing barrier fabrics, natural enemies, and sustainable management were developed by multiple institutions (eOrganic, University of Kentucky, Rodale Institute, Redbud Farm). A video on egg predation: <https://youtu.be/czzwuaqO1ec> was developed. Direct outreach events such as field days and grower meetings were held over 3 years of the project. Project findings were delivered to 35-4000 participants annually across MD, WV, PA, KY, TN, NC, and OH. BMSB identification materials were available to attendees from the NE IPM Center. Project team members discussed trap crops, insectary plantings, hot spots within farms, monitoring tools, and organic insecticide efficacy. Presentations at NOFA-NJ, MOSES, Great Lakes Fruit and Vegetable EXPO reached additional 200 farmers. **PUBLICATIONS (not previously reported):** 2012/09 TO 2017/08 1. Type: Journal Articles Status: Published Year Published: 2017 Citation: Mathews CR, B Blaauw, G Dively, J Kotcon, J Moore, D Pfeiffer, JF Walgenbach, C Welty, G Zinati, AL Nielsen. Evaluating a polyculture trap crop for organic management of *Halyomorpha halys* (Hemiptera: Pentatomidae) and endemic stink bugs in peppers. *J. Pest Science* 90:1245-1255 2. Type: Journal Articles Status: Published Year Published: 2017 Citation: Blaauw B^{*}, C Mathews, T Leskey, RW Morisson, AL Nielsen. Measuring host plant selection and retention of *Halyomorpha halys* (Hemiptera: Pentatomidae) by a trap crop. *Entomologia Experimentalis et Applicata* 163: 197-208 3. Type: Journal Articles Status: Published Year Published: 2017 Citation: Abram, PK, KA Hoelmer, A Acebes-Doria, H Andrews, EH Beers, JC Bergh, R Bessin, D Biddinger, P Botch, ML Buffington, M Cornelius, E Costi, ES Delfosse, C Dieckhoff, R Dobson, Z Donais, M Grieshop, G Hamilton, Tim Haye, Chris Hedstrom, MV Herlihy, M Hoddle, CRR Hooks, R James, P Jentsch, Thomas Kuhar, J Lara, JC Lee, A Legrand, T Leskey, D Lowenstein, L Maistrello, CR Mathews, JM Milnes, WR Morrison III, NK Joshi, AL Nielsen, E Ogburn, CH Pickett, K Poley, J Pote^{*}, PM Shrewsbury, E Talamas, L Tavella, J Walgenbach, R Waterworth, DC Weber, C Welty, N Wiman. 2017. Indigenous arthropod natural enemies of the invasive brown marmorated stink bug in North America and Europe. *J. Pest Science* 90:1009-1020 4. Type: Journal Articles Status: Published Year Published: 2017 Citation: Pote, J. M., and A. L. Nielsen. 2017. Life stage specific predation of *Halyomorpha halys* (St?) by generalist predators. *Biological Control* 114: 1-7 5. Type: Journal Articles Status: Published Year Published: 2016 Citation: Dobson R., M. Rogers and J.C. Moore R. Bessin. 2016. Exclusion of the Brown Marmorated Stink Bug from Peppers Using Barrier Screens. *HortTechnology* 26:191-198. Progress 09/01/15 to 08/31/16 Outputs Target Audience: Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? This project has provided training to graduate students at multiple institutions, post-doctoral researchers, and numerous undergraduates. How have the results been disseminated to communities of interest? We have provided training for the organic community through field days and extension meetings in multiple states. What do you plan to do during the next reporting period to accomplish the goals? We are in the final year of this project. Items still to be completed are: Webinars on biological control for BMSB, trap crops and whole-farm movement Completion of gut content analysis of predators for BMSB DNA Field evaluation of host plant volatiles as potential attractants for BMSB Impacts What was accomplished under these goals? PROJECT IMPACT: Through this large multi-state project we have developed tools to assist organic farmers and homeowners manage brown marmorated stink bug. Brown marmorated stink bug (BMSB) is an invasive agricultural pest but also spends the winter primarily inside homes,

causing significant nuisance to the general public. As part of a citizen science project we have identified that dark houses, primarily in wooded or wooded/agricultural areas have the highest numbers of overwintering BMSB. Key research findings of this project aimed to identify management tactics consistent with organic standards that minimized the use of chemicals. We incorporated multiple assessments of natural enemies (the good bugs) and found rates of predation to be 10-20%. This level of predation was much higher than was expected for an invasive pest. We also identified the use of barrier fabrics to protect high value, sensitive crops and we identified a trap cropping system. Trap crops use more attractive plants to deter the insects from the crop of interest. By using a combination of sorghum and sunflower we reduced levels of injury that would cause peppers to be unmarketable. We hope to incorporate flower plantings to attract key natural enemies and restructure the trap crop to improve management in the future. Our project findings have been shared with organic farmers, extension personnel and researchers across the country. We have published two manuscripts this year, with another one in review. Two extension factsheets, two webinars and two videos have also been developed.

Objective 1) Develop habitat manipulation tactics for stink bugs In 2014 and 2015 we evaluated a field-scale trial in cooperation with 7 organic farmers and 3 experiment stations. A polyculture of sunflower and sorghum surrounding peppers (*Aristotle* var.) were evaluated for population densities of BMSB, native stink bugs, natural enemies on both the trap crops, peppers within the trap crop and the control peppers (without a trap crop). The trap crop significantly reduced minor stink bug injury, but not major (>2 feeding sites/fruit). In 2015 we investigated the behavioral basis for trap crops by looking at dispersal between trap crop and peppers through harmonic radar and protein marking. Together these results suggest that minimal movement occurs between the trap crops and peppers and that BMSB released within the peppers moved furthest. Similarly, BMSB movement from the trap crop appeared to be arrested for a period of at least 7 days.

Objective 2) Whole-farm movement We utilized a mark-release-recapture experiment to track movement of nymphs among four host plants at progressive phenological stages. We found BMSB nymphs are making feeding choices and disperse to a more suitable crop depending on plant phenology. As seedlings, BMSB nymphs were more attracted to Swiss chard. As ears of corn were forming, more nymphs dispersed to sweet corn than to any other host plant. Similarly, at the end of August, nymphs dispersed to soybean as pods were forming. Headspace volatiles from each host plant were collected over progressive phenological stages to determine if there is an olfactory component to host attractiveness to BMSB nymphs. Five host plant volatiles were identified at these critical periods that may be responsible for host plant finding. Dispersal capacity of nymphs identified that 5th instars were capable of dispersing 2m/hr with speed increasing under higher temperatures. Lee, D-H, A.L. Nielsen, and T.C. Leskey. 2014. Dispersal capacity and behavior of nymphal stages of *Halyomorpha halys* (Hemiptera: Pentatomidae) evaluated under laboratory and field conditions. *J. Insect Behavior* 27: 639-651

Analysis identified hotspots in ornamental and fruit trees, typically in the family Rosacea. Objective 3) Determine natural enemies of BMSB A multi-state survey identified low levels of parasitism and predation on egg masses to be about 10-15%. Grasshoppers and damsel bugs were identified as key predator taxa. A microscopic photographic library of predator impacts and defined feeding damage categories was compiled to assist with identifying key predators attacking BMSB eggs in the field. Insectary plantings were evaluated to increase natural enemy response to BMSB. In MD and OH, partridge pea was studied in organic field corn and blackberry plantings. Overall there was a high rate of parasitism and predation of all stink bug eggs assessed, but the impact of natural enemies on BMSB did not appear to be enhanced through the addition of partridge pea. In NJ, perennial wildflower plots were established in 2014 and predation and parasitism within plots were assessed in 2015 and 2016. Despite an overall increase in the natural enemy community in the wildflower plots and higher predation due to piercing- sucking predators, there was no difference in chewing predation or parasitism between the control and wildflower plots. Rutgers has developed two DNA sequences that can be used to identify field-collected predators that have recently fed on BMSB and relative rates of predation. In late 2014, the Asian parasitoid species *Trissolcus japonicus* was collected from BMSB egg masses. *T. japonicus* is the primary parasitoid and biological control agent of BMSB in Asia and are likely a major role of keeping populations below damaging levels. Surveys were conducted in DE, MD, WV, TN, and NJ in organic crops and along wooded field borders to determine if *T. japonicus* was established in additional areas. Parasitoids were found in additional sites in MD and WV indicating that *T. japonicus* had survived the winter but had not spread to organic farms beyond that location.

Objective 4) Evaluate organic management options for BMSB Mechanical exclusion of stink bugs was studied using various sizes of mesh netting over organic bell peppers. Measurements on total yield, stink bug injury and natural enemy populations were made. There was a correlation between netting size and the proportion of the stink bug injury and all netting sizes reduced damage compared to the open controls. However, the finest mesh cages had secondary outbreaks of aphids due to exclusion of natural enemies.? Field trials on pepper and tomato evaluated the efficacy and rate of organic insecticides for control of stink bugs. BMSB was the most predominant species in pepper, and the most effective treatments included Veratran D at 15 lbs/acre (93% control of adults) and Azera at 56 oz/acre (68%). On tomato, the predominant stink bugs were native species, causing overall 50.6% damage to the harvestable fruit. Veratran D at 15 lbs/acre mixed with Azera at 16 oz/acre provided 46% control.? Insecticides, such as Entrust, were found to cause high mortality against egg parasitoid species *Telenomus podisii* and *Anastatus reduvii*.

Objective 5) Develop and deliver extension A Facebook community page, BMSB in Organic Farming Systems, has 153 followers from 10 different countries. The Facebook page was created to inform and update growers and the public on the status and results from this project. Results from this project have been disseminated through extension training sessions and presentations. KY and TN developed a factsheet covering the results from the evaluation of barrier fabrics to manage stink bugs. The Rodale Institute published a web article entitled "Organic Management of Brown Marmorated Stink Bug (BMSB)". A factsheet on natural enemies has been published on eOrganic - a combined effort from 8 institutions. Video on egg predation: <https://youtu.be/czzwuaqO1ec>

Publications Type: Journal Articles Status: Published Year Published: 2016 Citation: Ogburn, E.C. R. Bessin, C. Dieckhoff, R. Dobson, M. Grishop, K. A. Hoelmer, C. Mathews, J. Moore, A.L. Nielson, J.M. Pote, M. Rogers, C. Welty, and J.F. Walgenbach. 2016. Natural enemy impact on the invasive brown marmorated stink bug, *Halyomorpha halys* (Stink Bug) (Hemiptera: Pentatomidae), in organic agroecosystems: A regional assessment. *Biol. Control*. 101: 39-51. Type: Journal Articles Status: Awaiting Publication Year Published: 2016 Citation: Blaauw B, C Mathews, T Leskey, RW Morrison, AL Nielsen. Measuring host plant selection and retention of *Halyomorpha halys* (Hemiptera: Pentatomidae) by a trap crop. *Entomologia Experimentalis et Applicata*. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Ogburn, E., R. Bessin, C. Dieckhoff, R. Dobson, M. Grieshop, K. Hoelmer, C. Mathews, J. Moore, A. Nielsen, C. Welty, and J. Walgenbach. 2015. Natural enemy impact on invasive brown marmorated stink bug (*Halyomorpha halys*) eggs in organic agroecosystems: a multistate assessment. Entomological Society of America Annual Meeting. Minneapolis, MN. November 15, 2015. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: A Nielsen Invasion Biology of the Brown Marmorated Stink Bug: A Behavioral and Ecological Perspective 2016 ESA North Central Branch Mtg, Cleveland, OH Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: A Nielsen Incorporating behavior and population dynamics into management of the invasive *H. halys* in the USA 2016 Recent Trends in *H. halys* Research, Universit  di Modena e Reggio Emilia , Italy Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: JM Pote, AL Nielsen 2016 Life stage specific predation of *Halyomorpha halys* (Stink Bug) 2016 NE Plant, Pest, and Soils Conference, Philadelphia, PA Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: C Mathews, B Blaauw, AL Nielsen Integrating pheromone traps in a trap crop system for managing stink bugs in organic pepper production 2016 NE Plant, Pest, and Soils Conference, Philadelphia, PA Type: Journal Articles Status: Under Review Year Published: 2016 Citation: 32. Mathews CR, B Blaauw, G Dively, J Kotcon, J Moore, E Ogburn, D Pfeiffer, T Trope, JF Walgenbach, C Welty, G Zinati, AL Nielsen. Evaluating a polyculture trap crop for organic management of *Halyomorpha halys* (Hemiptera: Pentatomidae) and endemic stink bugs in peppers. Submitted to *J. Pest Sci* Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: A Nielsen Organic management of BMSB year 3 2015 December BMSB Working Group Mtg, Winchester, VA Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: JM Pote, DM Fonseca, R Valentin, AL Nielsen. Identifying predators of *Halyomorpha halys* using molecular gut content analysis. 2015 Entomol. Soc. Am, Portland, OR Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: B Blaauw, AL Nielsen Supporting natural enemies and their services with native wildflowers 2016 NE Plant, Pest, and Soils Conference, Philadelphia, PA Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Walgenbach, J.F., A. Herbert, T. Kuhar, D. Reisig and M. Toews. 2015. Distribution, pest status and research programs for the brown marmorated stink bug in the southeastern US. Entomology Society of America Annual Meeting Symposium on Brown Marmorated Stink Bug Working Group: Synergizing IPM research to deliver solutions. Minneapolis, MN. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Walgenbach, J., S. Schoof, and E. Ogburn. 2015. Phenology of brown marmorated stink bug in NC apples. Cumberland-Shenandoah Fruit Workers Conference, Winchester, VA. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Ogburn, E., and J. Walgenbach. 2016. The role of biocontrol in regulating brown marmorated stink bug (*Halyomorpha halys*) populations in North Carolina. SEB-Entomological Society of America Annual Meeting, Raleigh, NC. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Walgenbach, J.F. 2016. Impact of non-managed habitats on orchard arthropod communities. Symposium presentation at SEB-Entomological Society of America Annual Meeting. Raleigh, NC. Progress 09/01/14 to 08/31/15 Outputs Target Audience: The research collaborators have reached a broad audience through various outputs during the first year of this OREI project to develop behaviorally-based methods to organically manage stink bugs. Through the utilization of demonstration field days, we targeted organic farmers of many agronomic, vegetable, and fruit crops, as well as extension personnel and consumers. We also publicized our work through numerous local news and online programs to inform the general public on the importance of stink bug research and management. Changes/Problems: Along with Redbud Farms in WV, we included a third treatment where pyramid traps baited with BMSB aggregation pheromone plus a synergist were placed on each side of the trap crop plot and used to as a method to remove stink bugs from these plots. A demonstration plot of trap crops was added in KY. In MD, a sticky card to monitor natural enemy community was added to the trap crop study and expanded the sampling unit area to obtain more consistent

data, since the naturally-occurring stink bug infestation was low. The finding of *Trissolcus japonicus*, an Asian egg parasitoid of BMSB, in the US triggered additional sentinel egg mass surveys to determine presence and impact of this critical natural enemy. The survey was expanded to non-crop habitat in the wooded habitat surrounding organic farms as research suggests that this is a more suitable habitat for *T. japonicus*. To better understand the impact of native predators on BMSB, predation of identified predators (damselflies, katydids, lady beetles, etc.) were exposed to 1st and 2nd instar nymphs of BMSB. Additionally, the functional response of these predators against egg stages is being researched. What opportunities for training and professional development has the project provided? To date this project has helped support the training of 6 post-doctoral researchers, 12 graduate students and 22+ undergraduate student interns. Three students to date have successfully completed their Masters of Science in Entomology or Plant Pathology through this project. This year, 5 scientific manuscripts have been published or accepted to peer-reviewed publications. The project team has given 23 research talks and 11 presentations at extension meetings. Project members have provided training to over 240 master gardeners. The USDA conducted a parasitoid identification workshop to identify key characteristics of native species. The 'Great Stink Bug Count' trained over 300 participants each in 2013 and 2014 on identification of BMSB and is being utilized to identify key characteristics of houses that serve as overwintering structures for BMSB. The Walgenbach lab instructed the entomology class at Brevard College in a hands-on lab on the biology of BMSB and our work on its biology and natural enemies. Students also looked at BMSB feeding damage on apples and working with native parasitoid colonies, and gave the students a tour of the lab and research station. The Nielsen lab spoke at NOFA-NJ meetings in hands-on demonstration of trapping, natural enemies and identification. Additionally, research results have been communicated to researchers at regional and national meetings. How have the results been disseminated to communities of interest? The results of our project as well as basic biology and identification of BMSB have been disseminated widely to communities of interest in 11 states throughout the country through field days, grower meetings. Our project team has delivered 11 extension talks or presentations within the past year and produced 2 factsheets, a webinar and a video. We have also worked directly with over 10 organic growers in these states by conducting research at their establishments. At field days and extension meetings, a project summary tri-fold, sunflower seed packets and BMSB identification kits have been available. In NJ, approximately 25 organic growers attended an organic community meeting where BMSB biology, trap crop methods were discussed. Another 80 small farm and sustainable growers attended a workshop to learn about BMSB biology, trap cropping and insectary plants. Rodale demonstrated the trap cropping field experiment to over 100 visitors in PA. In WV, a field day was held at Redbud Farms to 35 participants and WVU also held a field day. Both sites demonstrated trap crop trials. In the Southeast, a poster presentation on habitat manipulation for stink bugs was seen by approximately 3,000+ attendees at the SE fruit and veg conference and 1,000+ attendees at the SSAWG meeting. A webinar highlighting BMSB predators and relevant information for organic producers by Y-L Park was presented to 108 participants and has had additional 400+ views on YouTube. The general public has also been an important component of our outreach programs. The second year results of the Great Stink Bug Count were summarized and sent to our citizen scientists. Participants were asked to participate in a follow-up survey about home invasion by BMSB, including extent of the problem, tactics used to control them in the home, and other assorted issues. What do you plan to do during the next reporting period to accomplish the goals? The next reporting period represents our last funding cycle. During this time period we are analyzing data and preparing multiple manuscripts for publication. Research on biological control agents, specifically on gut content analysis, life-stage specific predation, and functional response will continue. Additionally we have identified five potential host odors that might stimulate dispersal behavior in vegetable systems. We will investigate response to these odors in laboratory experiments. Dissemination of research findings to stakeholders will continue through the development of factsheets, webinars, and extension meetings. Impacts What was accomplished under these goals? Objective 1) Develop habitat manipulation tactics for stink bugs: We tested a third year of the evaluation of habitat manipulation through the use of trap crops, the planting of an attractive host plant surrounding a cash crop, to prevent or slow the injury of the cash crop by stink bugs. In 2014 and 2015, we conducted a field-scale experiment on the efficacy of sunflower and sorghum as a combined trap crop to protect bell peppers from stink bug pests. In 2014 the trap crops were attractive to BMSB and native stink bugs and delayed colonization of the pepper crop. In 2015, this was repeated at 7 farms in 6 states. In 2015 populations of the invasive BMSB were lower than previous years but native stink bug species were much higher than in previous years. Preliminary analysis reveals that, similar to 2014, the trap crops provided some protection from stink bug damage compared to unprotected peppers. In the initial selection of trap crop species, colonization by native stink bugs was an important factor in deciding which plant species to use and the selection of sunflower and sorghum is predicted to buffer changes in stink bug population densities. The results from 2014 suggest that under high and medium stink bug densities, the effectiveness of a trap crop might be improved with the integration of management tactics. Thus, Rutgers University and Redbud Farm evaluated a modification of the trap cropping treatment that included baited pyramid traps to remove stink bugs and hopefully enhance retention. This was conducted to determine if adding in a 'management' approach under medium pressure farms would increase the attractiveness. The

pyramid traps baited with the aggregation pheromone did not appear to benefit the removal of stink bugs and thus the reduction of pepper damage compared to trap crop plots without the traps. Objective 2) Determine factors affecting BMSB whole-farm movement: Over the 3-year period of this study we determined that BMSB nymphs have a high capacity for dispersal and readily disperse from one host to a more suitable host depending on plant phenology. During 2015 Rutgers utilized GC-mass spectrometry to identify host plant chemicals that correspond with the attractiveness of BMSB to host crops. Results show that there are five common plant odors released by the tested host plants that correspond to BMSB nymph attraction. In 2015 we analyzed data on whole-farm movement at three farms WV and NJ. Analysis identified hotspots in ornamental and fruit trees, typically in the family Rosaceae. In 2015 in MD, overwintering trapping parameters to increase the efficacy of collecting overwintering BMSB were investigated. White traps were the most attractive and collected the most bugs when either placed on the ground or up to 40 ft high. A citizen science project was also initiated that surveyed the public to describe their home, landscape, and stink bug infestations. In 2013 and 2014, roughly 150 data sets were collected from participants who counted BMSB on their homes, and results suggest brown homes situated in agricultural and woodland dominated landscapes have the highest populations of overwintering BMSB. Objective 3) Determine natural enemies of BMSB: The identity, activity, and importance of extant natural enemies of stink bugs in organic agroecosystems has been evaluated during the past three field seasons through a combination of sticky cards, video surveillance, sentinel egg masses, laboratory trials, and molecular diagnostics. In 2015, Redbud Farm and the USDA completed laboratory evaluations of predator (>450 individuals in >20 taxa) impacts on BMSB eggs. These results support the finding that katydids are a key predator group. A microscopic photographic library of predator impacts and defined feeding damage categories was compiled to assist with identifying key predators attacking BMSB eggs in the field. Additionally, Rutgers evaluated predation of BMSB eggs and nymphs to assess life-stage specific predation by various potential stink bug predators in the lab and identified damsel bugs and assassin bugs as key predators of other life stages. We evaluated insectary plantings to increase natural enemy response to BMSB. In MD and OH, partridge pea was studied in organic field corn and blackberry plantings. Overall there was a high rate of parasitism and predation of all stink bug eggs assessed, but the impact of natural enemies on BMSB did not appear to be enhanced through the addition of partridge pea. At Rutgers, perennial wildflower plots were established in 2014 and predation and parasitism within plots were assessed in 2015. Despite an overall increase in the natural enemy community in the wildflower plots and higher predation due to piercing-sucking predators, there was no difference in chewing predation or parasitism between the control and wildflower plots. As an additional method of identifying the importance of extant natural enemies, Rutgers has developed two DNA sequences that can be used to identify field-collected predators that have recently fed on BMSB. This will help us identify predators of BMSB and quantify the prevalence of BMSB predation in the wild. In late 2014, the Asian parasitoid species *Trissolcus japonicus* was collected from BMSB egg masses. *T. japonicus* is the primary parasitoid and biological control agent of BMSB in Asia and are likely a major role of keeping populations below damaging levels. Surveys were conducted in DE, MD, WV, TN and NJ in organic crops and along wooded field borders to determine if *T. japonicus* was established in additional areas. Parasitoids were found in additional sites in MD indicating that *T. japonicus* had survived the winter but had not spread to organic farms beyond that location. Objective 4) Evaluate organic management options for BMSB: Completed in previous years. Objective 5) Develop and deliver extension: Our Facebook community page, BMSB in Organic Farming Systems, currently has a total of 147 followers from 10 different countries. The Facebook page was created to inform and update growers and the public on the status and results from this project. Results from this project have been disseminated through extension training sessions and presentations. KY and TN developed a factsheet covering the results from the evaluation of barrier fabrics to manage stink bugs. The Rodale Institute published a web article entitled "Organic Management of Brown Marmorated Stink Bug (BMSB)". Redbud Farm in WV developed a factsheet on sustainable management techniques. Importantly a factsheet on natural enemies has been published on eOrganic - a combined effort from 8 institutions. Direct outreach events such as field days or grower meetings were held in various states. In 2015, Rodale (PA), NC, KY and TN had field days highlighting research, specifically trap crops to over 300 people. Redbud Farm held a field day to 35 participants and was attended by project team members from 3 institutions and was covered by local press. Project team discussed trap crops, overwintering site selection, insectary strips, pheromone-based trapping methods. BMSB identification materials developed through the NE IPM Center were distributed to attendees. PI Yong-Lak Park conducted a webinar hosted by eOrganic titled "Managing Bad Stink Bugs with Good Stink Bugs", which had 108 attendees and over 400 views on YouTube. Grower meetings also played a significant role in reaching stakeholders. Presentations at NOFA-NJ, MOSES, Great Lakes Fruit and Vegetable EXPO reached additional 150+ farmers. PI Blaauw, was interviewed on organic management tactic for BMSB by the American Vegetable Grower. Publications Type: Conference Papers and Presentations Status: Accepted Year Published: 2015 Citation: Hunt, L. G. and C.R.R. Hooks. 2015. Diversifying the arthropod community with partridge pea: Increasing natural enemies and controlling pests in organic field corn. Ecological Society of America. Baltimore, MD August 09-14, 2015. (Poster Presentation). Type: Conference Papers and Presentations Status: Accepted Year Published: 2015 Citation: Torri

J. Hancock, D.H. Lee, J.C. Bergh, W.R. Morrison, and T. C. Leskey. 2015. Utilizing citizen science to identify characteristics important to overwintering site selection for brown marmorated stink bug. Brown Marmorated Stink Bug Working Group Meeting. College Park, MD. Type: Conference Papers and Presentations Status: Accepted Year Published: 2015 Citation: Torri J. Hancock, D.H. Lee, J.C. Bergh, and T. C. Leskey. 2015. Utilizing citizen science to identify characteristics important to overwintering site selection for brown marmorated stink bug, *Halyomorpha halys* (Stål). Student Competition Poster, Eastern Branch of the Entomological Society of America. Rehoboth Beach, DE. Type: Conference Papers and Presentations Status: Accepted Year Published: 2015 Citation: Morrison, III W.R., C. Mathews, and T.C. Leskey. 2015. Pushing the frontiers of applied ecological science with the use of harmonic radar and micro-tagged insects to address questions related to the management of invasive species. 100th Annual Meeting of the Ecological Society of America, Baltimore, MD. Type: Conference Papers and Presentations Status: Accepted Year Published: 2014 Citation: Morrison, III W.R. and T.C. Leskey. 2014. Defending vegetables in organic production from the brown marmorated stink bug: Attraction and retention using trap crops. Brown Marmorated Stink Bug Northeast IPM Working Group Meeting, Winchester, WV. Type: Conference Papers and Presentations Status: Accepted Year Published: 2015 Citation: Morrison, III W.R., C. Mathews, and T. Leskey. 2015. Using harmonic radar to measure the retention capacity of trap crops for the invasive brown marmorated stink bug in organic pepper production. 85th Annual Meeting of the Eastern Branch of the Entomological Society of America, Rehoboth, DE. Type: Conference Papers and Presentations Status: Accepted Year Published: 2014 Citation: Morrison, III W.R., C. Mathews, and T. Leskey. 2014. Using harmonic radar to measure the retention capacity of trap crops for the invasive brown marmorated stink bug (Hemiptera: Pentatomidae) in organic pepper plantings. 62nd Annual Meeting of the Entomological Society of America, Portland, OR. Type: Other Status: Other Year Published: 2014 Citation: Morrison, III W.R. and T.C. Leskey. 2014. Using a carrot-and-stick approach: Attraction, retention, and management of brown marmorated stink bug in fruit and vegetables. Department of Entomology Seminar Series, Rutgers University, New Brunswick, NJ. Type: Conference Papers and Presentations Status: Accepted Year Published: 2015 Citation: Moredock, J. and Y.-L. Park. 2015. Biological control of *Halyomorpha halys* (Hemiptera: Pentatomidae) using *Podisus maculiventris* (Hemiptera: Pentatomidae). Annual Meeting of the Eastern Branch of the Entomological Society of America Meeting, Rehoboth Beach, DE. Type: Conference Papers and Presentations Status: Accepted Year Published: 2015 Citation: Goldner, J. and Y.-L. Park. 2015. Whole-farm spatial dynamics of *Halyomorpha halys* (Hemiptera: Pentatomidae) in organic farming systems. Annual Meeting of the Eastern Branch of the Entomological Society of America Meeting, DE. Type: Conference Papers and Presentations Status: Accepted Year Published: 2014 Citation: Park, Y.-L. 2014. Brown marmorated bugs in Korea: rearing, historical occurrence, and current status. BMSB Working Group Meeting, Winchester, VA. Type: Conference Papers and Presentations Status: Accepted Year Published: 2014 Citation: Ahn, J., C. G. Park, and Y.-L. Park. 2014. Spatial distribution of brown marmorated stink bug (Hemiptera: Pentatomidae) in cornfield: Implications for sampling. Annual Entomological Society of America Meeting, Portland, OR. Type: Conference Papers and Presentations Status: Accepted Year Published: 2014 Citation: Goldner, J., and Y.-L. Park. 2014. Seasonal movement of *Halyomorpha halys* (Hemiptera: Pentatomidae) in organic farming systems. Annual Entomological Society of America Meeting, Portland, OR. Type: Conference Papers and Presentations Status: Accepted Year Published: 2015 Citation: AL Nielsen 2015 Organic management of BMSB, 8th International IPM Symposium, Salt Lake City, Utah Type: Conference Papers and Presentations Status: Accepted Year Published: 2015 Citation: Deroshia, K., Grieshop, M. J. 2015. Identifying natural enemies of *Halyomorpha halys* using video surveillance in organic systems. Poster at North Central Branch Entomological Society of America Annual Meeting, Manhattan, KS. Type: Conference Papers and Presentations Status: Accepted Year Published: 2015 Citation: Deroshia, K., Grieshop, M.J. 2014, November. Monitoring for existing natural enemies of brown marmorated stink bug (*Halyomorpha halys*) using video surveillance in Michigan. Entomological Society of America Annual Meeting, Portland, Oregon Type: Conference Papers and Presentations Status: Accepted Year Published: 2015 Citation: C. Mathews, W.R. Morrison and T. Leskey. 2015. CSI egg mass damage: Tracking down unexplained predation of brown marmorated stink bug egg masses by native natural enemies. Ecological Society of America Meetings, Baltimore, MD Type: Conference Papers and Presentations Status: Accepted Year Published: 2015 Citation: C. Mathews, B. Blaauw, G. Dively, G. Zinati, J. Moore, J. Walgenbach, C. Welty, D. Pfeiffer, J. Kotcon and A. Nielsen. 2015. Developing trap crops for organic management of native and invasive stink bugs in peppers. Entomological Society of America Eastern Branch Meeting, Rehobeth, DE Type: Conference Papers and Presentations Status: Accepted Year Published: 2015 Citation: C. Mathews, W.R. Morrison III and T. Leskey. 2014. Fate of brown marmorated stink bug egg masses exposed to common generalist predators in the laboratory and in organic vegetable plots. Entomological Society of America National Meeting, Portland, OR Type: Journal Articles Status: Accepted Year Published: 2015 Citation: Nielsen, A., G. Dively, JM Pote, G Zinati, C Mathews. Identifying a Potential Trap Crop for a Novel Insect Pest, *Halyomorpha halys* (Hemiptera: Pentatomidae) in Organic Farms. Accepted, 2015. Env. Entomol. Type: Journal Articles Status: Awaiting Publication Year Published: 2015 Citation: Bessin, R., R. Dobson, M. Rogers and J.C. Moore. Exclusion of the Brown Marmorated Stink Bug from Peppers Using Barrier Screens. HortTech. In Press. Type: Journal

Articles Status: Published Year Published: 2014 Citation: Baek, S., Y. Son, and Y.-L. Park. 2014. Temperature-dependent development and survival of *Podisus maculiventris* (Hemiptera: Pentatomidae): implications for mass rearing and biological control. *Journal of Pest Science* 87:331340 Type: Theses/Dissertations Status: Accepted Year Published: 2015 Citation: Voshell, R. J. 2015. Interactions of brown marmorated stink bug, *Colletotrichum acutatum* and trap crops in organic tomato production. M.S. Thesis. West Virginia University. Morgantown, WV. Type: Journal Articles Status: Published Year Published: 2014 Citation: Mathews, C.R. and Barry, S. 2014. Compost tea reduces egg hatch and early-stage nymphal development of *Halyomorpha halys* (Hemiptera: Pentatomidae). *Florida Entomologist* 97(4):1726-1732. Type: Conference Papers and Presentations Status: Accepted Year Published: 2015 Citation: JM Pote, R Valentin, D Fonseca, and AL Nielsen. Using Molecular Techniques to Determine Natural Enemies of BMSB. Brown Marmorated Stink Bug Working Group Meeting. July 9, 2015. College Park, MD. Type: Conference Papers and Presentations Status: Accepted Year Published: 2015 Citation: BR Blaauw, R Isaacs, and AL Nielsen. 2015. The effect of native wildflower habitat on beneficial insects and their services. National Native Seed Conference, Santa Fe, NM. Type: Conference Papers and Presentations Status: Accepted Year Published: 2015 Citation: BR. Blaauw, GC Hamilton, C Rodriguez-Saona, and AL Nielsen. 2015. Understanding host choice to enhance the sustainability of brown marmorated stink bug management. Entomological Society of America Eastern Branch Annual Meeting, Rehoboth Beach, DE. Type: Conference Papers and Presentations Status: Accepted Year Published: 2014 Citation: Hunt, L. G. and C.R.R. Hooks. 2014. Effects of habitat manipulation on pest management in organic field corn systems. 4th Annual Northeast Area- BARC-UMD Symposium, Organic Food: Food, Health and Ecosystems. November 13, 2014. Beltsville, MD (Poster presentation).

2013/09 TO 2014/08 What was accomplished under these goals? This project is a cooperative effort unifying 13 institutions across 12 states. We have worked closely with organic growers to demonstrate the tactics we are researching and 9 participating growers have adopted such practices on their organic farms. Researchers have discussed the project to audiences over 500 people. Four post-doctorate scholars and 11 graduate students are receiving training through this project. The project has identified organic management tactics to reduce BMSB injury, key dispersal behavioral patterns, and important natural enemies. Our work has been communicated to a broad audience through traditional extension materials and social media. Objective 1 Develop habitat manipulation tactics for stink bugs: A trap crop is the planting of an attractive host plant surrounding a cash crop with the goal of preventing or slowing injury of the cash crop. Year 1 field trials indicated that sorghum and sunflower was the most attractive trap crop evaluated to BMSB. A field-scale experiment was conducted on the management potential of trap crops to protect bell peppers from stink bug pests. We evaluated sunflower and sorghum as a trap crop for BMSB at 11 farms in 7 states. The trap crop was attractive BMSB and native stink bugs and delayed colonization of the pepper crop. However, it may have artificially increased damage in the trap crop peppers late in the season. Similar results were observed with a sunflower trap crop for tomatoes in WV. We investigated behavior of BMSB within the trap crop to measure dispersal and utilization via inexpensive protein markers and harmonic radar in WV and NJ. Results suggest BMSB are retained longer and move less in the trap crop compared to the cash crop. In addition, the trap crop may pull BMSB from the cash crop and prevent the influx of new adults. Management within the trap crop is sometimes needed, especially with a pest that has a broad host range. Rutgers investigated management options, evaluating flaming, OMRI insecticides and BMSB aggregation pheromone. The aggregation trap removed the highest number of BMSB from the trap crop and will have minimal impact on natural enemies and will be incorporated into on-farm trap crop trials in Year 3. Azera also shows promise. Objective 2 Determine factors affecting BMSB whole-farm movement: We are investigating whole-farm movement for BMSB hotspots, nymphal dispersal, host plant choice and overwintering behaviors that will lead to management opportunities. Analysis at 3 organic farms identified hotspots in ornamental and fruit trees, typically in the family Rosacea. Crop hosts in 2014 showed BMSB favored peppers, black-eyed peas, and golden beets. We utilized a mark-release-recapture experiment to track movement of nymphs among four host plants at progressive phenological stages. We found BMSB nymphs are making feeding choices and disperse to a more suitable crop depending on plant phenology. Headspace volatiles from each host plant were collected over progressive phenological stages to determine if there is an olfactory component to host attractiveness to BMSB nymphs. We evaluated an overwintering trap to "trap out" fall populations of immigrating BMSB to help reduce the overall threat posed to crops the following spring. Traps were modified after 2013 results and are expected to provide a non-chemical management option. In fall 2013, a citizen science project was initiated to identify characteristics of human-made structures that promote their use as overwintering sites by BMSB, and the second year of data collection is currently underway. 300 participants counted BMSB on their homes, and results suggest agricultural and woodland habitats and brown colored houses had the highest populations. BMSB oriented mostly towards the North and East directions. In 2014, there are 225 participants. Objective 3 Determine natural enemies of BMSB: Natural enemy populations and activity in various organic crops are evaluated through either sticky cards or sentinel egg masses, which indicate biological control activity. The identify of predators and parasitoids of BMSB and native stink bug egg masses is being conducted through multiple approaches ranging

from molecular diagnostics to 48h monitoring of egg masses to understand the impacts of natural enemies in the organic agroecosystem. Nearly 32,000 BMSB eggs were placed in 6 states to assess predation in 2014. Predation was low, averaging at 4% with feeding by chewing and sucking predators. Parasitism was very low at 0.15% but many unhatched eggs may contain unemerged parasitoids. Day/night video cameras recorded predator visits to sentinel egg masses in NJ and MI and identified katydids as an important predator of BMSB eggs. Spined soldier bug was identified as a potential predator of BMSB in 2013 and the temperature thresholds for development were identified. Surveys in KY indicate higher parasitism rates of brown stink bug eggs compared to BMSB eggs. Species identification is still in progress. Insectary plantings may increase populations of natural enemies. Partridge pea was studied in organic field corn and blackberry plants in MD and OH. At Rutgers, perennial wildflower plots were established and predation and parasitism within plots were assessed. Despite being a first year planting with few blooms, there was an increase in predation and parasitism in BMSB egg masses that were placed in flower plots when compared to non-flower plots. Laboratory and field trials evaluated the impact of four OMRI insecticides on BMSB, egg parasitoids, and the predator community in soybean. Samples are currently being processed and the data will be analyzed to show possible impacts on individual taxa of natural enemies as well as overall community effects. Objective 4 Evaluate organic management plans for BMS: Mechanical exclusion of stink bugs was studied using various sizes of mesh netting over organic bell peppers. Laboratory studies indicated that netting smaller than 1/4" was needed to impede adult BMSB movement. Field studies evaluated sizes of 1/6", 1/8", and 1 mm mesh as a full season management tactic. Measurements on total yield, stink bug injury and natural enemy populations were made. There was a correlation between netting size and the proportion of the stink bug injury and all netting sizes reduced damage compared to the open controls. However, the finest mesh cages had secondary outbreaks of aphids due to exclusion of natural enemies. Field trials on pepper and tomato evaluated the efficacy and rate of organic insecticides for control of stink bugs. BMSB was the most predominant species in pepper, and the most effective treatments included Veratran D at 15 lbs/acre (93% control of adults) and Azera at 56 oz/acre (68%). On tomato, the predominant stink bugs were native species, causing overall 50.6% damage to the harvestable fruit. Veratran D at 15 lbs/acre mixed with Azera at 16 oz/acre provided 46% control. Objective 5) Develop and deliver extension materials: A Facebook community page, Brown Marmorated Stink Bug in Organic Farming Systems, was created to inform and update growers and the public on the status and results from this project. Participants from all cooperating states contributed pictures and cooperating growers were tagged in photos. Participants gave extension training sessions or talks. A handout was developed with eOrganic summarizing the project and distributed to 25 organic growers in NJ during a discussion about trap crops and biological control for BMSB. NCSU gave 2 training sessions on BMSB in organic systems to 75 people and participated in a field day at a cooperating farm with 35 extension professionals. Trap crop trials were highlighted at field days in MD, OH, KY, WV and PA for over 400 people. Our project's trap crop work was featured in Vegetable Growers Times following a presentation at the Mid-Atlantic Fruit and Vegetable Convention. **PUBLICATIONS (not previously reported):** 2013/09 TO 2014/08 1. Type: Conference Papers and Presentations Status: Other Year Published: 2014 Citation: Ahn, J, and Y.-L. Park. 2014. Development of Sampling Plans for Brown Marmorated Stink Bugs on Corn. Presented at Annual Meeting of Eastern Branch Entomological Society of America, Williamsburg, VA 2. Type: Conference Papers and Presentations Status: Other Year Published: 2014 Citation: Blaauw BR and AL Nielsen ?Whole-Farm Management Strategies for the Brown Marmorated Stink Bug? 2014 MOSES Organic Farming Annual Conference, WI 3. Type: Conference Papers and Presentations Status: Other Year Published: 2014 Citation: Pote J and AL Nielsen ?Determining the predators of Brown Marmorated Stink Bug: a multidisciplinary approach? 2014. Presentation at Annual Entomol. Soc Am Eastern Branch 4. Type: Journal Articles Status: Published Year Published: 2014 Citation: Lee, D-H, A.L. Nielsen, and T.C. Leskey. 2014. Dispersal capacity and behavior of nymphal stages of Halyomorpha halys (Hemiptera: Pentatomidae) evaluated under laboratory and field conditions. Journal of Insect Behavior 27: 639-651 5. Type: Journal Articles Status: Published Year Published: 2014 Citation: Baek, S., Y. Son, and Y.-L. Park. 2014. Temperature-Dependent Development and Survival of Podisus maculiventris (Hemiptera: Pentatomidae): Implications for Mass Rearing and Biological Control. J. Pest Sci. 87: 331-340 6. Type: Conference Papers and Presentations Status: Other Year Published: 2014 Citation: Park, C., J. Ahn, and Y.-L. Park. 2014. Brown Marmorated Stink Bugs in Korea: Insight from Historical and Current Data. Annual Meeting of Eastern Branch Entomological Society of America, Williamsburg, VA. 7. Type: Websites Status: Published Year Published: 2014 Citation: Facebook Page BMSB in Organic Farming Systems <https://www.facebook.com/bmsb.organic.management?ref=bookmarks> 8. Type: Websites Status: Published Year Published: 2013 Citation: eOrganic <http://eorganic.info/brown-marmorated-stink-bug-organic> 9. Type: Conference Papers and Presentations Status: Other Year Published: 2014 Citation: Deroshia, K. and M. Grieshop. 2013. Observing natural enemies of Brown Marmorated Stink Bug (Halyomorpha halys) using video surveillance in south- central Michigan. Presented at the Annual Meeting of the Entomological Society of America. November 11, 2013. Austin Texas 10. Type: Conference Papers and Presentations Status: Other Year Published: 2013 Citation: Goldner, J. and Y.-L. Park. 2013. Assessment of spined soldier bug (Hemiptera: Pentatomidae) as a predator of brown marmorated stink bug (Hemiptera: Pentatomidae). Presented

at Annual Meeting of Entomological Society of America, Austin, TX. 11. Type: Conference Papers and Presentations Status: Other Year Published: 2013 Citation: Baek, S., M. McKinney, J. Goldner, C. Park, B. Seo, and Y.-L. Park. 2013. Non-target effects of organic insecticides on *Podisus maculiventris* (Hemiptera: Pentatomidae). Presented at Annual Meeting of Entomological Society of America, Austin, TX. 12. Type: Conference Papers and Presentations Status: Other Year Published: 2014 Citation: Goldner, J., S. Baek, M. McKinney, and Y.-L. Park. 2014. Non-target effects of organic insecticides on *Podisus maculiventris* (Hemiptera: Pentatomidae). Poster at Annual Meeting of Eastern Branch Entomological Society of America, Williamsburg, VA.

2012/09 TO 2013/08 What was accomplished under these goals? Organic farmers in the mid-Atlantic states and some southern states are experiencing significant crop loss due to Brown Marmorated Stink Bug (BMSB). As an invasive species there are no co-evolved predators that mitigate population growth. The primary goal of this large, multi-state research project is to rapidly identify management tactics that will integrate with a whole-farm approach for BMSB while conserving the main ideals of organic farming, including conservation of natural enemies and biodiversity. This project unifies 13 institutions across 12 states with expertise in entomology, horticulture and organic management. We have conducted work in direct collaboration with organic growers and will seek further input from them in Years 2 and 3. To date, the project has trained 8 graduate students and 5 post-docs. Our primary outputs for Year 1 were to establish relationships with the organic growing community and collect data on management tactics and behavior. Many researchers in our team have focused on grower education and natural enemy surveys. We made significant accomplishments on the development of trap crops and natural enemy services, and filling knowledge gaps regarding dispersal behavior. In January 2013 researchers and cooperating growers met to discuss research updates and refine field trials for Year 1. We have continued to meet monthly through web-conferencing hosted by eOrganic and disseminate information through grower meetings. Obj. 1: Habitat manipulation tactics. Trap crops are a core tactic for managing insects by attracting and retaining the pest in a non-crop plant. Due to the broad feeding habits and mobile behaviors of BMSB we hypothesized this would be a suitable tactic. We tested four potential organic trap crops (sunflower, millet, sorghum, and okra) in four states for their effectiveness at attracting and retaining stink bugs. Results varied across the states, but sorghum was the most attractive trap crop tested (MD $P=0.046$; NJ $P=0.020$, WV $P=0.001$). For example, at Rodale Institute (PA) relative attractiveness of each trap crop to BMSB was 0.58, 0.29, 0.08 and 0.04 for sorghum, sunflower, millet, and okra, respectively. Across states, sunflower and millet had the highest number of BMSB eggs and native stink bugs. In Year 2 we will evaluate a polyculture of the top three trap crops. Pfeiffer (VT) and Kotcon (WVU) separately evaluated sunflower and/or sweet corn as trap crops. These appeared effective at attracting BMSB but injury was still reported on the tomato cash crop. PD Nielsen's lab began testing BMSB management strategies within the trap crop and found flaming to be the most effective organic management tactic evaluated. Obj. 2: Factors affecting whole-farm movement. We evaluated BMSB on-farm movement throughout the year at different spatial scales. At the field level we identified that nymphs are making feeding choices and will readily disperse to a more suitable crop depending on plant phenology. PD Nielsen and PI Hamilton (Rutgers) compared four organic crops; Swiss chard, bell pepper, sweet corn, and soybean. As seedlings, BMSB nymphs were more attracted to Swiss chard ($P=0.005$). As ears of corn were forming, more nymphs dispersed to sweet corn than to any other host plant ($P<0.001$). Similarly, at the end of August, nymphs dispersed to soybean as pods were forming ($P<0.001$). PI Leskey completed trials establishing flight dispersal capacity from wild BMSB populations. Leskey also began quantifying the rate of nymph dispersal and found 5th instars capable of dispersing 2m/hr with speed increasing under higher temperatures. Whole-farm movement was evaluated at 3 organic farms. PI Park characterized movement as aggregation within sheds moved to wooded areas and blackberry hosts. At one farm BMSB populations were then found in cherry and pear before moving to grape and then soybean. Final movement prior to overwintering was to corn and black locust. At the landscape level, year-long dispersal to/from overwintering sites was evaluated on-farm. Using pheromone traps, it was difficult to trap BMSB as they dispersed from shelters in the spring. We developed a simple trap to capture and remove BMSB in the fall as they dispersed to overwintering sites. PI Leskey also initiated a Citizen Science project aimed at identifying cues used by BMSB to select overwintering sites with 200+ volunteers. Together these projects will permit removal of source populations to reduce the following year's population. Obj 3: Impact of natural enemies on stink bugs. There are two main types of insect natural enemies: predators and parasitoids. Predators, like lady beetles and big-eyed bugs, eat many prey in a lifetime, generally feeding as juveniles and as adults. Parasitoids, which are generally small wasps or flies, are specialized insects that develop as a juvenile in one host, eventually killing it. Ten states covering Eastern, mid-Western, and Southern regions participated in this objective. Sentinel BMSB egg masses were deployed throughout the growing season to measure the impact of natural enemies in pepper, tomato, apple, soybean, corn, and numerous other crops. As an invasive species, BMSB has no specific predators or parasitoids. However, organic agriculture supports higher levels of natural enemies than conventional production and we hypothesized that their impact would be greater on BMSB, despite being generalists. Our results support this: PI Walgenbach (NCSSU) identified ca. 11.75% of BMSB eggs in organic systems were fed on compared to ca. 2.25% in conventional crops. WV organic field corn

had 51% of eggs fed upon by generalist predators where as only 0.1% eggs were parasitized by wasps. Across all states, organic corn, soybean, and apple had the highest portion of eggs fed on by natural enemies. A portion of the predator activity in NJ and MI was recorded with video cameras. In NJ we made the first observation of katydids consuming BMSB egg masses. Video has shown that the natural enemies attacking BMSB eggs include parasitoid wasps, lady beetles, sucking predators, katydids, and ants. Endemic stink bug species in MD field crops had a 5% hatch rate due to natural enemy activity whereas BMSB had a 55% hatch rate. BMSB egg masses had 38% parasitism while native species had 70%. While this is an excellent representation of natural enemy activity, it is clear that the natural enemy community does not 'prefer' BMSB eggs. To enhance natural enemy activity on BMSB eggs, conservation of parasitoids was investigated by PI Hooks (UMD) to identify insectary plants. Hook's data suggests that partridge pea should be evaluated further. The use of compost teas has also been evaluated by PI Mathews (Redbud Farm). Obj 4: Cultural control tactics specific to organic systems. In Year 1 PI Rogers (UTK) and Bessin (UK) and farmer Landis (Strawberry Creek Farm) investigated the use of barrier fabrics to prevent stink bug injury in vegetables. These row covers are able to reduce damage by BMSB and native stink bugs, with fine mesh fabrics providing more protection from insects and sunscald. However, fine netting reduced fruit production and natural enemy colonization. Exclusion may be a viable approach, but only under high levels of stink bug activity. Obj 5: Outreach. Outreach activities are in the early stages for this project after the first year of studies. WVU, Rodale Institute, UTK and UMD held field days where BMSB identification was discussed to groups ranging from 60-4000 participants. The tactics being investigated as part of this project were discussed, specifically predation of egg masses, organic insecticides and trap crops. eOrganic hosted a webinar by PD Nielsen and attended by 134 people describing BMSB biology, preliminary results and project objectives. Next year, our extension efforts will continue to evolve as data is analyzed. **PUBLICATIONS (not previously reported):** 2012/09 TO 2013/08 1. Type: Journal Articles Status: Under Review Year Published: 2014 Citation: Baek, S., Y. Son, and Y.-L. Park. 2013. Temperature-Dependent Development and Survival of *Podisus maculiventris* (Hemiptera: Pentatomidae): Implications for Mass Rearing and Biological Control. *J. Pest Sci.* 2. Type: Journal Articles Status: Accepted Year Published: 2014 Citation: Gawaly, S. and Y.-L. Park. 2014. Feeding Potential and Prey Acceptance of *Podisus maculiventris* (Hemiptera: Pentatomidae): Implications for Biological Pest Control. *J. Plant Biol. Soil Heal.* 3. Type: Websites Status: Published Year Published: 2013 Citation: Anne Nielsen, Brett Blaauw, and John McQueen. 2013. Website through eOrganic titled, ?Brown Marmorated Stink Bug in Organic Farming Systems.? (<http://eorganic.info/brown-marmorated-stink-bug-organic>) This website summarizes our OREI project and displays images, descriptions, and status updates from the first year of our project.

[↑ Return to Index](#)

Addressing Critical Pest Management Challenges in Organic Cucurbit Production

Accession No.	0230444
Subfile	CRIS
Project No.	NYC-149523
Agency	NIFA NY.C
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2012-51300-20006
Proposal No.	2012-02292
Start Date	01 SEP 2012
Term Date	31 AUG 2016
Grant Amount	\$1,962,562
Grant Year	2012
Investigator(s)	Mazourek, M.; Smart, C. D.; Hoffmann, M. P.; Colley, M.; Seaman, A. J.; Davis, J.; Murphy, J.; Ojiambo, P.; Stone, A.
Performing Institution	Plant Breeding, CORNELL UNIVERSITY, ITHACA, NEW YORK 14853

NON-TECHNICAL SUMMARY

This proposal will develop a suite of management options for three of the most significant pests challenging organic cucurbit producers: downy mildew, striped cucumber beetles and aphid-vectored viruses. The fundamental practices used by organic farmers to control pests, namely soil building for plant health, rotation, the available choice of plant varieties, and allowed insecticides and fungicides are not completely effective against any of the pests. For each of these challenges in cucumber, melon and summer squash, we have the genetics for host resistance and management approaches that have proven effective in preliminary trials and on-farm studies. Conducting on-farm trials and research into management options for the pests and pathogens will lead to innovative crop production strategies. Analyses of these results, economic analysis of the impacts of implementing these management options, and ongoing organic grower needs assessments will refine our understanding of factors that reduce yields, efficiency, productivity, and economic returns on organic farms. Integration of improved trap cropping, high tunnels and row covers as cultural control, plantings and biological growth promoters to reduce aphid-vectored viruses, and forecasting for cucurbit downy mildew will be a powerful systems approach for organic producers. We have extensive involvement of Cooperative Extension personnel who will co-develop and demonstrate our approaches with the end-users they serve in the regional organic agricultural community. Educational materials that are vetted by this process will be deployed online and coordinated with eXtension and eOrganic. Breeding and selection in organic systems for organic production and the trialing of new breeding lines and existing cultivars will focus on disease and pest resistance as plant trait goals, but quality and yield improvement are corollaries. The combined approach will develop, improve and evaluate systems-based integrated pest management programs to address pest and pest-related problems for organically grown crops and further benefits management of disease and insect pests in the Southeast. This collaboration between Northern and Southern states will allow sharing of resources. Partners in the South will gain from experiences that were generated from investment in Northern US organic production; partners in the North will gain experience with how familiar challenges are magnified by warmer weather and without the benefit of very cold winters that reduce pest and pathogen populations. Given the overall anticipated increase in pest pressure associated with a warming climate, research done today in more southerly regions in cucurbits and other crops will ultimately benefit agricultural systems to the north as shifts in distribution in pests and crops

occur. The best solution to tackling these challenges for these crops is the highly coordinated, complete systems approach that this team is poised to undertake.

OBJECTIVES

Our approach integrates plant selection and breeding with cultural pest management techniques that are implementable in the short term. Our specific objectives are: Breeding robust high quality cucumber, melon and squash open pollinated (OP) cultivars with tolerance to CDM, reduced attractiveness to SCB, and resistance to aphid-vectored viruses using existing germplasm; Evaluating and selecting cucumber, melon and squash cultivars and breeding lines for their performance under natural disease pressure on organic farms; Developing effective, affordable management strategies to address these pest challenges through the collaboration of growers, extension, and university researchers; and Conducting extensive outreach to facilitate grower adoption of the findings, developing networks of growers, extension and researchers in the Eastern US, and supporting the growth of organic cucurbit production, especially in the Southeastern US. In collaboration with eOrganic, we will establish an interactive online presence for communicating project results to the project team and a national audience, including photos and video clips. Social media tools, such as extension program's Facebook and Twitter feeds will direct users to these eOrganic and eXtension resources. The tangible results from the breeding projects will be new varieties and breeding populations with general characteristics that make them adapted to excel in organic production and specific traits that make them resilient to the pests and pathogens addressed in this project. We also expect to strengthen and develop partnerships between Northeast and Southeast regions through the work of the project, outreach events, and to strengthen community-building and networking. This network will be the foundation for long-term support to both organic variety development and organic variety trialing. Researchers and agricultural professionals will better engage in research with farmers and their awareness of organic growers needs and participatory research benefits will increase. We will evaluate this impact through post-workshop evaluations following a logic model. Availability of scientifically valid evaluations will assist organic farmers in considering cultivar choices that will facilitate adoption of organic seed sources. Evaluation in organic systems with farmer involvement will also provide valuable feedback to project breeders directing future breeding activities. We will assess progress in our breeding material in comparison to existing cultivars through replicated trials on research farms and working organic farms along the eastern US and comparison to existing cultivars. Management strategies will be assessed based on their efficacy compared to no intervention, economic cost-benefit analysis using data compiled from organic growers and grower adoption of the strategies. Outreach materials will be assessed by the number of views on eOrganic or eXtension and attendance at meetings. The germplasm generated from the work will be used as breeding lines or directly as varieties by organic growers. Management strategies will be adopted by growers based on their farms' needs.

APPROACH

The nine breeding objectives within this proposal address three pest/pathogen challenges in three different crops. These resources will be enabled by efficient approaches to the breeding process that are modeled on farmer participatory plant breeding strategies, pathologist and entomologist collaborators guiding the phenotyping, and an extensive research station-grower farm network developed along the Eastern US to determine the suitability and adaptability of the materials in comparison to commercial cultivars. We are able to take advantage of high selection pressure from naturally occurring pathogens and pests that occur in our breeding plots on Cornell's Freeville Organic Farm to accurately reflect the pressures that might affect area growers. Inevitably we select for a combination of resistance traits each season. Cucurbit downy mildew and cucumber beetles are found reliably in our plots along with gummy stem blight, aphids and powdery mildew. Limited occurrences of CMV and Potyvirus infection are also observed. Our breeding strategies vary by the inheritance of the trait, ease of hand pollinating the crop and prevalence in our area. The knowledge generated by organic variety trials, downy mildew resistance assay, striped cucumber beetle assay, and virus resistance assay component of the research will be made readily available to a national audience by posting to the "Organic Variety Trial Database" that is curated by the Organic Seed Alliance and hosted on eOrganic. Additionally, we will employ the usual and well established mechanisms of sharing data at grower meetings, field days and project partners' websites. Cultivar and breeding line performance will also function to inform the breeding program of broad adaptability and to gauge progress, needs and potential. Cultivar choice and breeding for improved varieties for organic systems are key aspects to address on-farm needs. However, cultivars with exceptional quality or other grower/consumer driven attributes may lack the required resistance traits. Breeding for those traits takes several crop generations and therefore does not provide an immediate solution. Thus, it is essential to have short-term, implementable management strategies to protect not-resistant cultivars and to extend the benefit and longevity of any resistance genetics. These focus areas will include simplified trap cropping for organic growers, aphid vectored virus management,

use of high tunnels and row covers, improved forecasting for organic chemical control of downy mildew and economic analysis of these management strategies. Outreach to facilitate adoption and implementation of the findings is essential to the project. We will engage farmers and extension as active participants, develop an interactive online presence, increase participation of organic farmers in the CDM ipmPIPE, train students in organic systems research and develop an interactive online presence through eOrganic and eXtension.

PROGRESS

2012/09 TO 2017/08 Target Audience: Organic vegetable growers in the Eastern US and Canada want support for pathogen and insect mitigation and are the primary target of this proposal. However, as conventional growers adopt IPM practices and need alternatives to fungicides as cucurbit downy mildew develops resistance to these pathogens. We have continued to improve content on eOrganic with videos, webinars, trial reports, informational guides and tools for growers. Extension educators benefit from having timely access to new information about new cultivars through their association with the project, attending events and In-Service conferences about cultivars. Vegetable seed companies serving regions impacted by cucurbit downy mildew, striped cucumber beetles and potyviruses have received seed for evaluation, breeding and distribution. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Rachel Hultengren obtained her MS in Plant Breeding with a minor in communication with Dr Mazourek. As part of her training she produced videos for eOrganic in collaboration with growers and researchers. Lauren Brzozowski is a PhD student with Dr Mazourek leading the downy mildew resistance breeding for this project Emily Rodekohr, a technician with Dr Mazourek entering the employee Master's degree program with Mazourek with a minor in economics participated in the economic analysis. Annie Richard, working on on-farm breeding for organic grower needs in Kingston, ON spent the summer with us learning experiment design, breeding methodology for resistance to these pests and pathogens. Seven graduate students have participated in this project. How have the results been disseminated to communities of interest? Extension educators participating in this proposal have gained new content to share with their growers that they were able to integrate into their formal and informal grower interactions. In addition to the conferences, blog posts and workshops listed in products, we have shared webinars and informational videos on eOrganic that have been collectively viewed over 5,000 times. Managing Cucurbit Downy Mildew on Organic Farms: 203 views, Managing Striped Cucumber Beetles on Organic Farms: 203 views, Viral Diseases in Cucurbits webinar video: 546 views, Management Options for Striped Cucumber Beetle in Organic Cucurbits webinar: 2072 views, Challenges in Organic Cucurbit Production: 871 views, Managing Cucurbit Downy Mildew in Organic Systems in the Northeast webinar: 888 views, Cuckoo for Cucurbit Vine Crop Breeding webinar: 345 views. The project website (<http://eorganic.info/cucurbits>) has been accessed 3118 times. We have also offered new germplasm produced by this project to others working on cucurbit research grant proposals and seed companies. The named cultivars generated by this project in "products" are available commercially including through seed companies based in the Southeast. Virus resistant squash germplasm is being studied as part of CucCAP (2015-51181-24285) and the downy mildew resistant cucumber cultivars are the foundation of breeding resistant pickle cultivars as part of "A Production System for High Value Crops at Risk from Downy Mildew: Integrating Detection, Breeding, Extension, and Education" (2016-68004-24931). What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported

2015/09 TO 2016/08 Target Audience: Vegetable growers in the Eastern US and Canada want support for pathogen and insect mitigation. They regularly rate losses to cucurbit downy mildew and striped cucumber beetles as some of their primary challenges. This was echoed in a recent needs assessment survey of vegetable growers in the Northeast (<https://ecommons.cornell.edu/handle/1813/44636>). In the Southeast, growers commonly cited other insect challenges as additional challenges to production: squash bugs and vine borers. Overall this community would be served by new cultivars that were resistant to these pests and pathogens as well as recommendations for improved OMRI approved chemical controls such as organic insecticides and cultivars that were matched to different production techniques such as wilt resistant cucumbers for high tunnel production. Seed companies serving these growers look for improved seed options to offer these growers and performance advice on how these new cultivars will perform. Extension educators benefit from having timely access to new information about cultivars and practices. Changes/Problems: Significant losses of the cucumber breeding program to deer feeding were remedied by upgraded fencing for the 2016 season. What opportunities for training and professional development has the project provided? Katie Neufeld is a PhD student in the Ojibwa group. Her work focused on refining downy mildew forecasting the logistic regression models. David Robb is a PhD student at Clemson and worked with co-PI Murphy on cultivar trials, data collection and management in addition to describing results at a field day. David mentored two undergraduates that assisted with the data collection. Lauren Brzozowski is a PhD student in the Mazourek group. Lauren has been leading the breeding

work for cucurbit downy mildew resistance in cucumber. She has been managing crossing, selection and variety trials specific to the breeding program and is mentored by co-PI Chris Smart on the pathology work. She is also leading the summer squash breeding for striped cucumber beetle non-preference in cooperation with the Hoffmann group. Lauren has had the opportunity to present on her research at field days and conferences where she appears as a co-author. Undergraduate students in the Mazourek group learned skills associated with variety trials. How have the results been disseminated to communities of interest? Three field days in the Southeast and two in the Northeast reached over 200 people and shared the results of variety trials, efforts to breed for resilience in cucurbit crops, new cultivars, and how pest and pathogen challenges for these crops are managed on an organic farm. On farm trials allowed growers to explore the utility of new cultivars on their farms in comparison to market standards. Seed meetings were organized at the Carolina Farm Stewardship Association conference in addition to a presentation on the project. At the Virginia Association of Biological Farmers conference a presentation was made on the project and the development of a regional organic seed system. At the Georgia Organics conference booth promoted this project and the development of a regional organic seed system. Updates about the project and regional seed system development were published in the OSA quarterly newsletter. A poster was presented at the American Society for Horticultural Science. A presentation on breeding for striped cucumber beetle non-preference and downy mildew resistance was made at the Organic Seed Growers Conference. Two peer-reviewed journal articles were published. What do you plan to do during the next reporting period to accomplish the goals? Additional trials will be performed that quantify impact of the most effective cultural practices that have been observed in the course of the project. Cultivar performance with and without downy mildew pressure will be compared so growers have better information about variety choice and how it impacts yield at different times of year and the cost benefit differences of application on emerging, effective OMRI approved fungicides on resistant and susceptible cultivars. High tunnel yields with bacterial wilt resistant cucumber cultivars will be repeated to define the value of this characteristic for this system. Similarly for virus associated losses the yield of plants with and without virus pressure will be compared with also a consideration of impact of plant resistance. Publications and guides will be prepared that describe the results of the trials.

2014/09 TO 2015/08 Target Audience: The target audiences for this project during this third reporting period were primarily organic vegetable growers in the eastern United States and seed companies that serve these growers. Seed companies were an increasingly important part of the project as PI Mazourek met with them at field days and tradeshows to explore breeding needs and support their growth and efforts to supply regionally appropriate cultivars. Growers were reached through interactions at conferences, networking to identify research farm hosts and the planning of research on their farms. The website on eOrganic <http://eorganic.info/cucurbits> shared information broadly. We also reached out to the greater public about the impact and potential of food choices that include production system and cultivar choice. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? A post-doctoral associate specializing in entomology assisted with the project and mentored a new graduate student before starting a faculty position at another university. A new graduate student joined the Mazourek group to lead the CDM resistant cucumber breeding and squash breeding for striped cucumber beetle non-preference and was mentored by her peers, the post-doctoral associate and project affiliated faculty. Students published their work in peer reviewed journals with the mentorship of their faculty advisors. Seed companies gained new regionally appropriate seed and were trained in grafting techniques for high tunnel production of cucurbits that will be further disseminated to other growers at the NOFA-NY winter conference. How have the results been disseminated to communities of interest? In collaboration with Blue Hill restaurant, we initiated a campaign to introduce the public to the benefits of tromboncino squash. Tromboncino was featured on the summer menu and diners were both treated to a delicious course and they were informed about the benefits to sustainability of growing a squash that could be produced in organic conditions without neonicotinoid insecticides or row cover. This was experienced by thousands of diners at the restaurant. A guide was made to show squash vulnerability to beetles and made available to growers at field days, Empire Farm Days in NY and shared via our eOrganic website. Interactions with growers and networking in the Southeast continued to reach new growers to participate in trials try new breeds on their farm. The Vegetable Breeding Institute field days shared trial and breeding updates with representatives from more than 30 seed companies. Field days were held in NC that showcased the variety trials. A poster was presented at the ASHS meeting to share our progress with this audience of peers. What do you plan to do during the next reporting period to accomplish the goals? To generate economic data on the impact of downy mildew resistant cucumbers trials will be performed both early and later in the season to provide in-season guidance on when to plant resistant cultivars. New types of downy mildew resistant cucumbers will be evaluated in high tunnel production versus open field to evaluate performance in the two environments and to the different challenges in those environments. A third year of replicated trials will be performed with a refined set of cultivars that have excelled for both previous years of trials. A new row cover option is available for use in the Southeast that is a coarse mesh that is promising for excluding beetles without heat buildup that can damage plants. Preliminary evaluations will do done to explore the potential for this product. Data will be compiled and analyzed

from the life of the project for presentation in webinars and lessons learned short videos to share results with growers on eOrganic. We will support the growth of new seed capacity in the SE by supporting grant applications and sharing materials and insight with new projects emerging in the region.

IMPACT

2012/09 TO 2017/08 What was accomplished under these goals? Multiple new cultivars were developed with resistance to key pests and pathogens. Trifecta muskmelon has cucurbit downy mildew (CDM) resistance. DMR264 and DMR401 cucumbers are the first with resistance to the new strain of CDM. Martini cucumber excelled at yield and quality in all regions. A bacterial wilt resistant cucumber hybrid was developed that was found to solve wilt issues that can be the major cause of plant mortality in high tunnels. Interspecific hybrids that we thought would be useful as early flowering trap crops for striped cucumber beetles (SCB) were not highly attractive to SCB. Instead they have potential as SCR resistant alternatives to highly SCB vulnerable *C. maxima* winter squash. Eight breeding lines were developed for zucchini type squash with SCB resistance/non-preference. We have characterized these new cultivars in the context of multistate variety trials with on-farm daughter sites. This has revealed cultivar productivity, disease resistance and also uncovered unexpected challenges. For example, cucumber cultivars that are grown in SC in late summer because of their CDM resistance are exposed to pickle worm that can devastate the crop. With grower input we have included unanticipated market classes in our trials. For example, smaller melons are favored by CSA's and some growers are interested in growing *C. moschata* species, harvested and sold at the immature stage, as replacements for zucchini due to their superior insect resistance. We have a better understanding of how to manage cucurbit downy mildew in organic systems. More growers are aware of the reporting and forecasting tool at <http://cdm.ipmpipe.org/> through discussion of the tool at field days, conferences and webinars. They are now aware that they don't need to destroy infected crops, a practice that was a barrier they identified as reducing their participation in reporting. Also, organic growers now have fungicides that provide improved control of the pathogen which provides value to the improved forecasting capabilities. We have released resistant cultivars with guidance on planting them at times of year when the pathogen is predicted to arrive in a given region. We have been able to make strides in understanding and characterizing the pathogen and developing ways to store spores for future study; as an obligate biotroph it is very hard to culture in the lab without these innovations. We have characterized the virus resistance of cucurbits using strains of the viruses native to the SE US. While many cultivars do not exhibit symptoms when infected, there are some, notably cultivars and breeding lines from Cornell, that do not get infected at all and do not accumulate virus. These are good candidates for breeding projects because they can reduce the potential source of inoculum on an organic farm that could spread to other crops that didn't have symptom suppression characteristics. This strategy for reducing inoculum is especially relevant in the management of a virus like CMV, which is much less cucurbit-specific than ZYMV and has a broad host range that includes many weeds and crop plants. Striped cucumber beetles (SCB) are particularly devastating to squash cultivars. We have been able to parse out patterns of this damage by market class and subspecies. This has implications for breeding, production and cultural controls. Zucchini is much more vulnerable than straightneck/crookneck summer squash. For our breeding work we have made crosses between the two types to transfer resistance/non-preference to zucchini. We have explored implications for trap cropping. Highly preferred golden zucchini cannot be protected by a Blue Hubbard trap crop. Green zucchini can be protected by a trap crop. Summer squash are so non-preferred they can be free from damage even with no trap crop or other intervention. The economic analysis was undertaken to assess the impact of different cultural controls on pest and pathogen performance. Striped cucumber beetle (SCB) defoliation of squash was a primary concern. Row cover is commonly used as a physical barrier to protect transplants from SCB. Kaolin clay is also commonly sprayed on crops to deter beetle feeding. Questions for the analysis were: Do these treatments enhance profits; does their value change during the season and are they cultivar dependent?. An economic tool was developed, in the form of an easily managed spreadsheet tailored for growers, that factored in labor costs, farm size, material costs and market prices obtained from the NOFA-NY price index. Results showed that although kaolin clay was effective at reducing SCB feeding damage, marketable yield was not increased for any cultivar or planting date. Row cover was effective at both reducing damage and increasing yield in SCB vulnerable cultivars when SCB pressure was significant during early plant growth. Yields of SCB resistant/non-preferred cultivars were not aided by physical barriers or kaolin clay. High tunnel improved earliness and yield of cucumbers, however mid-season plants were prone to mortality due to bacterial wilt. Late season plants were lost to *Alternaria* if they were a susceptible genotype. A gothic high tunnel design excluded CDM, but it was highly variable if a more humid caterpillar design would be free from CDM or completely lost. A late season open field planting could be highly productive in the fall in the NE if resistant cultivars were used but otherwise compared to a high tunnel, a total loss could be expected. **PUBLICATIONS (not previously reported):** 2012/09 TO 2017/08

1. Type: Journal Articles Status: Published Year Published: 2017 Citation: K.N. Neufeld, A.P. Keinath, P.S. Ojiambo, A model to predict the risk of infection of cucumber by *Pseudoperonospora cubensis*, *Microbial Risk Analysis*, Volume 6, 2017, Pages 21-30, 2. Type: Journal Articles Status: Other Year Published: 2018 Citation: J.F. Murphy and M. Mazourek Evaluation of cucumber, melon and squash varieties for response to three Potyvirus species and Cucumber mosaic virus. in prep 3. Type: Journal Articles Status: Awaiting Publication Year Published: 2017 Citation: Lange, H.W., Smart, C.D. and Seaman, A.J. 2017. Evaluation of materials allowed for organic production on downy mildew of cucumber, 2016. *Plant Disease Management Report*. Volume 11 4. Type: Journal Articles Status: Awaiting Publication Year Published: 2017 Citation: Lange, H.W., Smart, C.D. and Seaman, A.J. 2017. Evaluation of materials allowed for organic production on powdery mildew of zucchini, 2016. *Plant Disease Management Report*. Volume 11

2015/09 TO 2016/08 What was accomplished under these goals? The basis for striped cucumber beetle preference in *Cucurbita pepo* was further explored with a focus on the contrast that was observed between straightneck summer squash and golden zucchini. Windtraps were utilized to test the role of volatile compounds in beetle attraction. Differences in attractiveness between these two squash was observed when intermediate numbers of male cucumbers were applied to plants. Plant volatiles were collected from plants with and without beetle feeding to identify volatiles that may be involved in beetle preference. Trap cropping experiments continued to explore efficacy and beetle emergence from trap crops. In 2016, 'Golden Zucchini' was added as a trap crop. Results showed that trap crop destruction by mowing and rototilling had mixed effect on adult emergence from eggs laid on trap crop plants. This suggests that trap destruction, at least by these methods, does not reduce subsequent striped cucumber beetle pressure. When the highly preferred 'Golden Zucchini' was used as the crop being protected by the trap crop 'Blue Hubbard', protection was not adequate. We conclude that trap cropping in this system only works well when the trap crop is paired with a substantially less preferred cultivar. Breeding for reduced preference in the zucchini market class therefore continues to be an important goal. Collection continued of isolates of the cucurbit downy mildew pathogen to determine pathogen diversity. Our results to date continue to support the hypothesis that there is isolate variation by host (those isolates that attack pumpkin and squash are different from those on cucumber) but not by geographic region within NY. An efficacy trial to identify OMRI-approved products for the control of cucurbit downy mildew found the rhamnolipid product Zonix (a commercially available fungicide) was significantly better than all other treatments at the second rating (four days after symptoms were observed on August 26) and was the only product that was significantly better than the untreated control at the final rating. Cucurbit downy mildew forecasting was further refined with information about the impact of different variables on spray decision thresholds. The utility and value of participation in the CDM forecasting network. The final year of replicated, multisite trial concluded. New releases from this project were included in these trials. Three publicly bred cucumbers have been released as part of this project. DMR-NY401 is commercially available for 2017. It has competitive earliness and was outstanding during periods of moderate to high downy mildew pressure. DMR-NY264 is commercially available and has superior resistance but is later to produce. Martini is commercially available for 2017 and has been one of the highest yielding cultivars in the trials when downy mildew pressure has not been severe. Trifecta melon was developed through this project and excels in these trials. Summer squash and zucchini are still being developed and are not ready for trialing; through an approach of exposing them to massive amounts of cucumber beetles at the transplant stage we are able to select for those that receive little feeding damage.

****PUBLICATIONS (not previously reported):**** 2015/09 TO 2016/08 1. Type: Journal Articles Status: Published Year Published: 2016 Citation: Brzozowski L, Holdsworth WL, Mazourek M. 'DMR-NY401': (2016) A New Downy Mildew-Resistant Slicing Cucumber. *HortScience*. 51:1294-1296. 2. Type: Journal Articles Status: Published Year Published: 2016 Citation: Brzozowski L, Leckie BM, Gardner J, Hoffmann M, Mazourek M. 2016. Subspecies Delineates Striped Cucumber Beetle (*Acalymma vittatum*) Preference in *Cucurbita pepo*. *Hort Research*. 3:16028. 3. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Mazourek M, Hultengren H, Brzozowski L. 'Creating Plant Breeding Populations for Organic Systems.' Organic Seed Growers Conference. Corvallis, OR. February 5, 2016. 4. Type: Journal Articles Status: Published Year Published: 2016 Citation: Frost E, Mazourek M, Davis J, Zystro J. 'Breeding Cucurbits for Organics in the SE Region.' Carolina Farm Stewards Association Conference. November 8, 2015. 5. Type: Conference Papers and Presentations Status: Other Year Published: 2016 Citation: Mazourek M. 'Organic Farming Systems.' Terroir Symposium. Toronto, ON. April 25, 2016. 6. Type: Conference Papers and Presentations Status: Other Year Published: 2016 Citation: Mazourek M. 'Vine crops genetics: What's on the Horizon??' Empire State Producers Expo. Syracuse, NY. January 20, 2016. 7. Type: Other Status: Published Year Published: 2016 Citation: Hubbard K. CFSA Guest Blog, Why the Southeast Seed Movement Matters to Farmers Everywhere, <https://www.carolinafarmstewards.org/why-the-southeast-seed-movement-matters-to-farmers-everywhere/> 8. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Poster. Mazourek et al. ESO-Cuc, the Eastern Sustainable Organic Cucurbit Project. American Society for Horticultural Science. Atlanta, GA. August 9. 2016.

2014/09 TO 2015/08 What was accomplished under these goals? Ten melon breeding lines that were superior in 2014 breeding trials were evaluated in replicated trials along with representative control cultivars. Given the wet summer and use of row cover to protect plants from beetles, angular leaf spot infections were particularly severe. Four lines were identified as promising combinations of quality and yield compared to the controls. Cucumber breeding was continued as in 2014. Promising lines were evaluated in replicated trials that included all commercial available green slicing cucumbers advertised as resistant to downy mildew. None of these commercial cultivars were resistant in our trials in NY and their yield was reduced accordingly when planted into downy mildew disease pressure. The best of these breeding lines will be released as 'DMR401' after its 2015 plot designation. Squash seedlings from F2 populations from crosses between preferred zucchini and non-preferred summer squash were germinated in the greenhouse and exposed to field harvested striped cucumbers. Only those that survived were transplanted to the field for pollination. Other populations were selected for lack of beetle damage, earliness and lack of spines. Replicated trials were conducted on promising interspecific crosses between winter squash that were originally intended as new trap crops. Instead these were discovered to have promise to deliver winter squash with the quality of *C. maxima* species with less vulnerability to striped cucumber beetles. These had very high quality, flowered more than 3 weeks earlier than their parental cultivars and showed excellent storage. Melon and cucumber striped cucumber beetle preference assays were repeated without neighboring squash plots to compete for beetle pressure. Preference continuums were discovered with no clear demarcation of preferred or non-preferred cultivars as was discovered in squash. A second year of data was collected on squash to publish our findings on preference contrasts by *Cucurbita pepo* subspecies. Laboratory assays demonstrated *P. cubensis* isolates from squash are genetically distinct from cucumber and cantaloupe isolates. We supported Fruition Seeds in a SARE grant to test the performance of our interspecific squash hybrids as rootstocks for grafting melons with fusarium resistance that was overcome by the pathogen. All performed well in grower high tunnels in terms of disease resistance; all surpassed the Charentais melon that the grower had been using with resistance to some races of fusarium. Harvested fruit were however noticeably different in appearance than those from ungrafted plants which might impact marketability. We performed trials to compare the impact of row cover on the yield of summer squash that were non-preferred by striped cucumber beetles to zucchini that were highly preferred and thus sustained significant damage. Row cover protected both from damage, each only sustaining 10% defoliation after row cover was removed. Summer squash without row cover had similar minimal amounts of damage, but yielded half as much. Zucchini was 50% defoliated and yielded 25% as much as plants protected by row cover. New cultivars that were introduced performed well. Tromboncino squash were not as early to produce but produced consistently without beetle damage and their indeterminate habit allowed them to continue growing despite mildew pressure. **PUBLICATIONS (not previously reported):**

2014/09 TO 2015/08 1. Type: Journal Articles Status: Published Year Published: 2015 Citation: Gardner J, Hoffmann MP, and Mazourek M. 2015. Striped Cucumber Beetle (Coleoptera: Chrysomelidae) Aggregation in Response to Cultivar and Flowering. *Environmental Entomology*, 44:309-316. 2. Type: Journal Articles Status: Published Year Published: 2015 Citation: Summers CF, Gulliford CM, Carlson CH, Lillis JA, Carlson MO, Cadle-Davidson L, Gent DH, Smart CD. 2015. Identification of Genetic Variation between Obligate Plant Pathogens *Pseudoperonospora cubensis* and *P. humuli* Using RNA Sequencing and Genotyping-By-Sequencing. *PLoS One*. <http://dx.doi.org/10.1371/journal.pone.0143665> 3. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Holdsworth W, Summers C, Glos M, Smart C, Mazourek M. Breeding for Downy Mildew Resistance in Cucumber. *Cucurbitaceae*. Bay Harbor, MI. October 12-16, 2014. 4. Type: Conference Papers and Presentations Status: Other Year Published: 2014 Citation: Barber D, Mazourek M, Jones S and Bethony J. ?The Future of Flavor: Looking Beyond Heirlooms?. The 9th Annual StarChefs.com International Chefs Congress. Brooklyn, NY. October 26-28, 2014. 5. Type: Other Status: Published Year Published: 2015 Citation: Poster. Mazourek M, Davis J, Hoffmann M, Colley M, Murphy J, Ojiambo P, Seaman A, Smart C, Kleese T, Hadad R, Steward C, Reid J. ESO-Cuc Eastern Sustainable Organic Cucurbit Project. American Society for Horticultural Science. New Orleans, LA. August 6, 2015. 6. Type: Conference Papers and Presentations Status: Other Year Published: 2015 Citation: Kemble J, Frost E, Mazourek M. ?Disease Management for Vegetables: Making Better Use of Sustainable Management Practices and Disease Resistant Varieties?. Mini-Course. Southern SAWG Conference. Mobile, AL. January 27-30, 2015. 7. Type: Conference Papers and Presentations Status: Other Year Published: 2015 Citation: Colley M, Mazourek M. State of Organic Seed Listening Session. NOFA-NY Winter Conference. Saratoga Springs, NY January 23, 2015. 8. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Colley M, Frost E. Fundamentals of Organic Seed Production. Carolina Farm Stewardship Association Conference. Greenville, SC. November 11, 2014.

[↑ Return to Index](#)

Creating an Organic Plant Breeding Center

Accession No.	0230566
Subfile	CRIS
Project No.	NC09249
Agency	NIFA NC.
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2012-51300-20024
Proposal No.	2012-02236
Start Date	01 SEP 2012
Term Date	31 AUG 2015
Grant Amount	\$1,262,855
Grant Year	2012
Investigator(s)	Reberg-Horton, S.; carter, T. E.; murphy, J. P.; goodman, M. M.; isleib, T. G.
Performing Institution	Crop Science, NORTH CAROLINA STATE UNIV, RALEIGH, NORTH CAROLINA 27695

NON-TECHNICAL SUMMARY

The long-term goal of this project is to increase the sustainability of organic agriculture by insuring continual improvement of the genetic base for organic field crops. We seek to create a center that will breed for traits needed by organic farmers, conduct on-farm testing of advanced lines, collaborate with growers at meetings and field days to be held every year, and foster a seed distribution system amongst organic farmers. This project builds on the success of a former OREI-funded project and seeks to institutionalize the relationships we have developed into a center that will serve the organic community for decades. The impetus for our project grew directly out of a series of farmer panel discussions hosted by North Carolina State's Organic Cropping Systems Program. At these panel discussions, farmers voiced concern over increasing privatization of breeding, decreasing availability of GMO-free varieties, and lack of breeding under organic conditions. This project fits squarely under OREI priority four, to: "Strengthen organic seed systems... goals of organic seed systems proposals can include, but are not limited to: disease and pest resistance, stress tolerance, quality and yield improvement, and genetic mechanisms to prevent inadvertent introduction of GMO traits through cross-pollination." Our new center has the intention and capability to release corn hybrids resistant to GMO contamination, increase weed competitive ability in soybeans, find seedling disease resistance in peanuts, discover allelopathic wheat lines through our newly developed protocols, and to increase the yield of all four crops under organic conditions.

OBJECTIVES

Long-term Goal The long-term goal of this project is to increase the sustainability of organic agriculture by improving farmer access to cultivars adapted to organic systems. An ongoing commitment to this goal is needed and is best accomplished by the creation of a regional center. **Objectives:** To achieve this long-term goal, the following main objectives are proposed: 1. Create regional opportunities for plant breeders and farmers to define breeding targets and develop methods of achieving those targets. Both live and video-conferenced meetings for breeders and farmers in our region will be utilized to bring participants together. 2. Screen breeding material submitted by breeders around the region for specific farmer- defined breeding targets utilizing protocols we have developed over the last three years. 3. Screen advanced generation material submitted by breeders around the

region for performance in organically managed field trials. 4. Build a farmer-led crop improvement model for organic seed production. Expected Outcome: Building a farmer-led crop improvement model for organic seed production Multiple barriers are preventing farmers from having access to cultivars that are better performers than what is currently available to them. One factor is the small size of the organic market in an era of highly consolidated seed companies. Large companies are barely interested in regions outside the Midwest, much less organic farmers in our region. Smaller companies have begun targeting organics but they do not necessarily have varieties adapted to our region. If our center is to be successful, it must involve more than breeding. We must address how new releases will be distributed.

APPROACH

The long-term goal of this project is to increase the sustainability of organic agriculture by insuring continual improvement of the genetic base for organic field crops. We seek to create a center that will breed for traits needed by organic farmers, conduct on-farm testing of advanced lines, collaborate with growers at meetings and field days to be held every year, and foster a seed distribution system amongst organic farmers. This project builds on the success of a former OREI-funded project and seeks to institutionalize the relationships we have developed into a center that will serve the organic community for decades. The impetus for our project grew directly out of a series of farmer panel discussions hosted by North Carolina State's Organic Cropping Systems Program. At these panel discussions, farmers voiced concern over increasing privatization of breeding, decreasing availability of GMO-free varieties, and lack of breeding under organic conditions. This project fits squarely under OREI priority four, to: "Strengthen organic seed systems"... goals of organic seed systems proposals can include, but are not limited to: disease and pest resistance, stress tolerance, quality and yield improvement, and genetic mechanisms to prevent inadvertent introduction of GMO traits through cross-pollination." Our new center has the intention and capability to release corn hybrids resistant to GMO contamination, increase weed competitive ability in soybeans, find seedling disease resistance in peanuts, discover allelopathic wheat lines through our newly developed protocols, and to increase the yield of all four crops under organic conditions.

PROGRESS

2012/09 TO 2016/08 Target Audience: Organic corn, soybean, wheat and peanut farmers were the target audience for our project along with county extension and other agricultural professionals who advise them. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? We hold a winter conference each year to discuss progress with the farmers and get feedback. Our partner organization Rural Advancement Foundation International hosts a session where farmers who participated in one of the advanced line trials on-farm get to talk about their favorites. This year, a session will be dedicated to on-farm hybrid corn production for the new double cross hybrid we have released. In July of each year, we host a summer field day where our advanced line trial is held and farmers can see firsthand how new lines are performing relative to commercial checks. How have the results been disseminated to communities of interest? Seeds from several of these commodities will soon be available commercially as detailed in the accomplishments section. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported

2012/09 TO 2013/08 Target Audience: Organic row crop producers and buyers. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? We hold multiple meetings per year with farmers. A mid July tour is held to look at the organic trials of the advanced soybean lines. Farmers get to walk the fields and make their own comments about the entire. At the last field day, one of the farmers who had hosted an advanced line trial on his farm shared his experience with one. He had found a line with cotyledons further up the stem than usual that made cultivation easier. This trait had previously gone unnoticed in our tests. In February, we hold a workshop to discuss breeding progress and advanced line results from all four crops, corn, soybeans, wheat and peanuts. How have the results been disseminated to communities of interest? Findings are primarily disseminated on our website <https://organicgrains.ces.ncsu.edu/> When new results are published, farmers and educators receive an email and/or tweet depending on what format they have selected. Our subscribers now span most of the southeastern states. What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported

IMPACT

2012/09 TO 2016/08 What was accomplished under these goals? Corn Three years ago, NC State began a collaboration with the University of Guadalajara to identify new sources of Dominant Gametophytic Factors (DGF's). That collaboration has been highly successful and has resulted in our ability to provide new source of pollen blockage to breeders around the country. Our aggressive shipment of these seeds to other public breeders and publication of the new DGF's was done to prevent patenting of these genes at the request of our University of Guadalajara colleagues (Jones et al 2016; Sanchez et al. 2011). We also collaborated with NIFA on a press release for the most recent publication, <<https://www.cals.ncsu.edu/agcomm/news-center/perspectives/block-that-pollen/>>. These new DGF's are now sufficiently within the public domain to prevent easy patenting. In North Carolina, we continue to work on new hybrids that take advantage of these new crossing barriers. We have also continued to pursue double cross hybrids for organic corn because of the reduction in seed production costs when seed must be produced organically. Our best hybrid seed was produced on three farms in North Carolina for the farmers to grow their own seed and to be able to sell to their neighbors. All three farmers were new to hybrid corn seed production but will continue to produce this seed in 2017. Several of our hybrids are being pursued for acquisition by private seed companies and will be available commercially within the next two years. Soybeans We have developed protocols to screen soybeans for competitiveness with weeds. Multiple methods of measuring soybean canopies were tested to predict their competitive ability (Place et al. 2011a). Directly measuring competitive ability, as done in this study, is extremely expensive as it involves growing the crop in competition with weeds and then separating crop and weed biomass to assess the outcome. Fortunately, one of the techniques, overhead image analysis of the soybean canopy combined with pixel counting software, was sufficiently predictive to allow it to serve as an indirect measure of competitive ability. We utilized this approach to screen 45 entries chosen to represent as wide a range in growth patterns as possible (Figure 1, adapted from Place et al. 2011a and Place et al. 2011b). Heritable variation in competitive ability is present in soybean and we have used these results to screen germplasm from the national soybean collection and our advanced lines from the USDA NC soybean breeding program. For the last three years, we have combined this screening approach with an ultra-narrow row production of soybeans (row spacing at 4.5"). The genetic differences in weed competitiveness are even more pronounced in the ultra-narrow rows. Unfortunately some competitive genotypes are more prone to lodging in these rows, but some genotypes could be found that were both competitive and lodging resistant. Two manuscripts are in preparation from this work and are currently published in the M.S. thesis of Jeremy Machacek available electronically at NC State libraries. Three new soybean lines have been released to North Carolina Foundation Seed in conjunction with this project. We have one year from this spring to apply for PVP protection for the cultivars if we can find a sufficient number of seedsmen interested in producing them. Peanuts Although the Southeastern USA has more peanut production and exportation (<<http://www.ers.usda.gov/Data/StateExports/>>) than any other region in the country, most organic peanut production occurs in New Mexico and West Texas (<http://www.ers.usda.gov/Data/Organic/>). Southeastern organic growers would like to add this crop to their rotation, but seedling diseases have presented a seemingly insurmountable problem (Ruark and Shew 2010; Kokalis-Burelle et al. 1997). Stand reductions of over 50% have been observed in our on-farm trials. Gaps in the peanut stand allow weeds to become established and can make the entire field impossible to harvest with a peanut digger. Since the advent of efficacious fungicidal seed treatments, peanut breeders have not had a reason to select for resistance to seedling diseases because the treatments are cheap, effective, and strongly recommended in conventional production practices (Spears et al. 2002). We have developed assays to screen old lines and exotic germplasm. Seedling diseases affecting peanut are of the genera *Aspergillus*, *Fusarium*, *Pythium*, and *Rhizoctonia*. As with any assay, providing uniformity of pressure from these organisms is key to finding genetic variation. Inoculating with *Fusarium* produces little disease while our *Rhizoctonia* assay is perhaps too aggressive. *Aspergillus* and *Pythium* have been more successful and are being used to screen hundreds of genotypes from the peanut genotype core collection. Resistant lines are fed into two breeding approaches. One of those approaches is a mass selection program where the peanuts are grown in the absence of fungicides. Highly susceptible genotypes do not survive to reproduction, providing a low labor approach to selection. Peanuts harvested from this field each year are screened for seed size to maintain the large seed trait and replanted the following year. Since this method produces far more seed than we need, each years newly improved population is made available to farmers. Several have continued to plant the updated seed each year with germination rates showing signs of improvement. Wheat The limiting factor for organic wheat production in the Southeast is Italian ryegrass (Weisz et al. 2013). Once this non-native weed becomes well established in an organic field, wheat must be removed from the rotation. Research was initiated in fall 2010 to: a) identify protocols for screening wheat genotypes for competitiveness with ryegrass in field trials and b) to evaluate genetic diversity in eastern US wheat varieties for allelopathic activity against ryegrass (Lemerle et al. 2001). Allelopathic wheat lines exude chemicals from their roots that prevent the germination and growth of weeds (Spruell 1984; Wu et al. 2000). Wheat to rye biomass ratio prior to harvest was correlated with various visual, spectral signal and overhead photography measurements taken during the growing season. The number of ryegrass heads per square meter was highly correlated with

biomass ratio and early growth pattern during the October to March period influenced ryegrass growth (Worthington et al. 2013) We trialed 60 cultivars and advanced lines two years in a row to screen for ryegrass suppression. The best genotype from that experiment (Featherstone VA258) suppressed ryegrass by 44% (Worthington et al. 2015). Considering the minimal cost to farmer of switching varieties, this additional tool in the fight against ryegrass can be instantly adopted by growers. We have continued to refine exactly what traits make the most competitive wheat. Molecular marker searches have revealed that day length sensitivity genes are the most correlated, more evidence that early to elongate in the spring varieties with a highly erect habit are the most competitive. Selection for these traits is possible while still maintaining a medium maturity wheat that will not risk late frosts. Two manuscripts are in preparation from this work and are currently published in the M.S. thesis of Matthew Granberry available electronically at NC State libraries. **PUBLICATIONS (not previously reported):** 2012/09 TO 2016/08 No publications reported this period.

2012/09 TO 2013/08 What was accomplished under these goals? Three years ago, NC State began a collaboration with the University of Guadalajara to identify new sources of DGFs. That collaboration has been high successful and has resulted in our ability to provide new source of pollen blockage to breeders around the country. Our aggressive shipment of these seeds and publication of the new DGF's was done to prevent patenting of these genes at the request of our University of Guadalajara colleagues (Jones et al 2016; Sanchez et al. 2011). We also collaborated with NIFA on a press release for the most recent publication, <https://www.cals.ncsu.edu/agcomm/news-center/perspectives/block-that-pollen/>. These new DGF's are now sufficiently within the public domain to prevent easy patenting. We have developed protocols to screen soybeans for competitiveness with weeds. Multiple methods of measuring soybean canopies were tested to predict their competitive ability (Place et al. 2011a). Directly measuring competitive ability, as done in this study, is extremely expensive as it involves growing the crop in competition with weeds and then separating crop and weed biomass to assess the outcome. Fortunately, one of the techniques, overhead image analysis of the soybean canopy combined with pixel counting software, was sufficiently predictive to allow it to serve as an indirect measure of competitive ability. We utilized this approach to screen 45 entries chosen to represent as wide a range in growth patterns as possible (Figure 1, adapted from Place et al. 2011a and Place et al. 2011b). Heritable variation in competitive ability is present in soybean and we have used these results to screen germplasm from the national soybean collection and our advanced lines from the USDA NC soybean breeding program. Although the Southeastern USA has more peanut production and exportation (<http://www.ers.usda.gov/Data/StateExports/>) than any other region in the country, most organic peanut production occurs in New Mexico and West Texas (<http://www.ers.usda.gov/Data/Organic/>). Southeastern organic growers would like to add this crop to their rotation, but seedling diseases have presented a seemingly insurmountable problem (Ruark and Shew 2010; Kokalis-Burelle et al. 1997). Stand reductions of over 50% have been observed in our on-farm trials. Gaps in the peanut stand allow weeds to become established and can make the entire field impossible to harvest with a peanut digger. Since the advent of efficacious fungicidal seed treatments, peanut breeders have not had a reason to select for resistance to seedling diseases because the treatments are cheap, effective, and strongly recommended in conventional production practices (Spears et al. 2002). We have developed assays to screen old lines and exotic germplasm. Seedling diseases affecting peanut are of the genera *Aspergillus*, *Fusarium*, *Pythium*, and *Rhizoctonia*. As with any assay, providing uniformity of pressure from these organisms is key to finding genetic variation. Inoculating with *Fusarium* produces little disease while our *Rhizoctonia* assay is perhaps too aggressive. *Aspergillus* and *Pythium* have been more successful and are being used to screen hundreds of genotypes from the peanut genotype core collection. Resistant lines are fed into two breeding approaches (details in methods section). The limiting factor for organic wheat production in the Southeast is Italian ryegrass (Weisz et al. 2013). Once this non-native weed becomes well established in an organic field, wheat must be removed from the rotation. Research was initiated in fall 2010 to: a) identify protocols for screening wheat genotypes for competitiveness with ryegrass in field trials and b) to evaluate genetic diversity in eastern US wheat varieties for allelopathic activity against ryegrass (Lemerle et al. 2001). Allelopathic wheat lines exude chemicals from their roots that prevent the germination and growth of weeds (Spruell 1984; Wu et al. 2000). Wheat to rye biomass ratio prior to harvest was correlated with various visual, spectral signal and overhead photography measurements taken during the growing season. The number of ryegrass heads per square meter was highly correlated with biomass ratio and early growth pattern during the October to March period influenced ryegrass growth (Worthington et al. 2013) We trialed 60 cultivars and advanced lines two years in a row to screen for ryegrass suppression. The best genotype from that experiment (Featherstone VA258) suppressed ryegrass by 44% (Worthington et al. 2015). Considering the minimal cost to farmer of switching varieties, this additional tool in the fight against ryegrass can be instantly adopted by growers. **PUBLICATIONS (not previously reported):** 2012/09 TO 2013/08 1. Type: Journal Articles Status: Published Year Published: 2016 Citation: Jones, Z. G., Goodman, M. M., & Krakowsky, M. D. 2016. Identification of maize-derived dominant gametophyte factors. *Euphytica* (Ahead of Print, DOI 10.1007/s10681-016-1635-0) 2. Type: Journal Articles Status: Published Year Published: 2015 Citation: Jones, Z. G., Goodman, M. M., & Krakowsky, M. D. 2015.

Identification of resistance to the Ga1-m gametophyte factor in maize. *Euphytica* 206:785-791. 3. Type: Journal Articles Status: Published Year Published: 2015 Citation: Worthington, M., S.C. Reberg-Horton, G. Brown-Guedira, D. Jordan, R. Weisz, and J. P. Murphy. 2015. Morphological Traits Associated with Superior Weed Suppressive Ability of Winter Wheat against Italian Ryegrass. *Crop Science* 55:50-56. 4. Type: Journal Articles Status: Published Year Published: 2014 Citation: Worthington, M., S.C. Reberg-Horton, G. Brown-Guedira, D. Jordan, R. Weisz, and J. P. Murphy. 2014. Relative Contributions of Allelopathy and Competitive Traits to the Weed Suppressive Ability of Winter Wheat Lines against Italian Ryegrass. *Crop Science* 55:57-64. 5. Type: Journal Articles Status: Published Year Published: 2013 Citation: Worthington, M.L. and S.C. Reberg-Horton. 2013. Breeding cereal crops for enhanced weed suppression: optimizing allelopathy and competitive ability. *Journal of Chemical Ecology* 39:213-231. 6. Type: Journal Articles Status: Published Year Published: 2013 Citation: Worthington, M.L., S.C. Reberg-Horton, D. Jordan, and J.P. Murphy. 2013. A comparison of methods for evaluating the suppressive ability of winter wheat cultivars against Italian ryegrass (*Lolium perenne*). *Weed Science* 61:491-4999.

[↑ Return to Index](#)

Alternative Post-harvest Washing Solutions to Enhance the Microbial Safety and Quality of Organic Fresh Produce

Accession No.	0230137
Subfile	CRIS
Project No.	TEN02012-02247
Agency	NIFA TEN
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2012-51300-20005
Proposal No.	2012-02247
Start Date	01 SEP 2012
Term Date	31 AUG 2016
Grant Amount	\$1,990,879
Grant Year	2012
Investigator(s)	Zhong, Q.; Critzer, F.; Davidson, P. M.; Wszelaki, A.; Lockwood, D.; Perkins-Veazie, P.; Drake, M. A.; Ducharme, D.; Baros, J.; Davis, J.
Performing Institution	Food Science & Technology, UNIVERSITY OF TENNESSEE, 1331 CIRCLE PARK DR

NON-TECHNICAL SUMMARY

Production of organic fruits and vegetables relies on careful oversight and appropriate inputs at every step in the growth, harvesting, processing, packaging, storage, and transportation. Care must be taken at every point in the supply chain to minimize the risk of produce being contaminated with foodborne pathogens such as, Shiga-toxin producing *Escherichia coli* (e.g., O157:H7) and non-STEC, *Listeria monocytogenes*, and *Salmonella*. Because many fruits and vegetables are consumed with minimal processing, foodborne illnesses caused by these pathogens are threats to the wellbeing of consumers, especially the elderly, infants, fetuses of pregnant women, and the immune-suppressed. This integrated project proposal to the USDA AFRI Organic Agriculture Research and Extension Initiative Program addresses the third priority area to "develop and improve allowable food safety practices to reduce microbial contamination, while increasing shelf-life of organic fresh produce." The long-term goal of this project is to provide safe, alternative, sustainable and effective treatments to prevent or reduce human pathogen contamination of organic produce. To improve microbiological safety of organic produce, there is an urgent need to develop washing practices that not only enhance sanitization effectiveness but also fulfill the requirement of organic sustainability. In this proposal, integrated research and extension objectives are proposed to improve current sanitization/washing practices. These will include fundamental approaches to understand surface properties of fresh produce and implement permitted surfactants in washing solutions to overcome capillary forces to enable more efficacious use of chlorine. In addition, novel sanitization strategies are proposed using organic essential oils to sanitize produce with and without chlorine. Economic feasibility, impacts on shelf-life and sensory properties of sanitization practices will be evaluated. Effective practices developed through research will be rapidly disseminated through extension to organic producers using media, electronic outlets, and on-farm testing. Integrated extension activities will be an important component directly improving microbial safety and quality of organic produce products in two southeastern states. The successful integration of research and extension can be implemented in organic production in other states.

OBJECTIVES

The efforts of this integrated project will be focused on developing alternative organic antimicrobials that can be incorporated into postharvest processing water. To increase sanitizer effectiveness, the research component of this proposal will include strategies to (1) improve the access of chlorine to microenvironments on produce surfaces and (2) develop and validate alternative sanitization agents and protocols. For the former (Objective 1), we will utilize surfactants allowed for organic production to overcome the capillary force in microenvironments on produce surfaces. For the latter (Objective 2), we will develop technologies to solubilize organic plant essential oils that have shown a wide array of antimicrobial activity in other food systems but have limited water solubility in their native state. The solubilized essential oil will be studied for sanitization alone or in combination with chlorine. Conditions optimized in Objectives 1 and 2 will be used for in-field testing in Objective 3. Impacts of improved and alternative sanitization conditions will be studied for shelf-life and sensory tests in Objective 4, while the economic feasibility will be analyzed in Objective 5. The extension activities include the engagement of stakeholders, with six organic producers in North Carolina and Tennessee serving a four-year period on a Board of Advisors, development and implementation of producer workshops, and development of multi-media extension materials.

APPROACH

The integrated project has research and extension components. The first research objective is to probe surface properties of organic fresh produce and develop strategies of improving sanitization effectiveness of washing solutions. Surfactants permitted for organic production will be studied for the potential of overcoming the capillary force on organic fresh produce and improving sanitization effectiveness of chlorine solutions. Cocktails of *Escherichia coli* O157:H7, *Listeria monocytogenes*, and *Salmonella* will be prepared from 5 strains associated with outbreaks due to consumption of contaminated fresh produce. The bacteria will be inoculated on organic carrots, cherry tomatoes, cantaloupes, and leafy greens (romaine lettuce and spinach), and the sanitization effectiveness will be evaluated after treatment, along with residual chlorine and surfactant concentrations. The second objective is to study technologies of dissolving plant-derived food antimicrobials as alternative sanitization agent. The solubilized organic essential oil (EO) will be studied for sanitization alone or in combination with chlorine. The third objective is to in-field test the strategies developed in Objectives 1-2. Three research stations with USDA certified organic sites will be used, one located in Tennessee and two in North Carolina, which will utilize organic production standards for growing one cultivar of tomatoes and lettuce. All treatments will be evaluated on site in year three and fully replicated in year four. The fourth objective is to characterize impacts of alternative sanitization agents on sensory and quality. Romaine lettuce and cherry tomato will be used as the test crops for top 6 antimicrobial combinations from Objective 1 (chlorine +surfactant) and top 6 antimicrobial combinations from Objective 2 (EO or EO + chlorine), with comparison to two controls of water only and 150 ppm chlorine. The fifth objective is to conduct economic analysis of the alternative washing solutions. Extension activities will be fully integrated into all aspects of the research, beginning with involvement of organic stakeholders through a Board of Advisors. Their input and guidance on research objectives, success criteria, review of outreach material and media will assure that the research and extension activities are appropriately targeted. The utility of these alternative antimicrobial systems will be shared in several media types to assure appropriate distribution and on-going use for those in the organic fruit and vegetable industry. Varying delivery and means of communication will facilitate a dialogue amongst organic fruit and vegetable industry members that will be ongoing part the project's timeline and emphasize the importance of appropriate food safety interventions during the processing of fresh organic produce. Progress 09/01/12 to 08/31/17 Outputs Target Audience:Scientific community, growers, and the produce industry. Changes/Problems:In Objective 1, effects of adding surfactants in chlorine washes to improve disinfection efficacy were not pursued after the finding that adding gum arabic at 1% in 200 ppm chlorine solution actually reduced the efficacy of decontaminating *Salmonella* on cherry tomatoes. The research team decided to study an alternative water-based sanitizer, Citrox, that has been approved for organic production in UK but not yet in USA. In Objective 5, a true cost-benefit analysis of alternative washing solutions was not completed because of the limited availability of pricing information for commercialized products. What opportunities for training and professional development has the project provided?The project supported various personnel for different durations: two technicians, 4 post-doctoral researchers, 9 graduate students varying from 8 months to 4 years, and 20 undergraduate researchers as hourly workers. Three post-doctoral researchers after training were employed as faculty members in research universities in the United States and the fourth continued for post-doctoral training. Graduate students participated in the project continued for pre- and post-doctoral trainings or were hired by food and agricultural companies. Two undergraduate researchers are now in the graduate school. Three day-long workshops were offered in North Carolina and Tennessee for a total of eighty nine participants. A series of field presentations (Field Days) allowed for practical information to be presented to various audiences that include organic and conventional growers, regulators, scientists, students and natural conservation officials: Alternative Crops and Organics Field Tour, Mountain Horticultural Crops, Waynesville, NC (August 2015, 85 participants); Pick Tennessee Conference, Knoxville, TN (February 2016, 12 participants); Organic Field Day, Mountain Horticultural

Crops, Waynesville, NC (August 2016, 105 participants); Mountain Horticultural Crops Research Station Field Days, Waynesville, NC (July 2016, 201 participants); Tomato Field Day, Mountain Horticultural Crops Research and Extension Center, Mills River, NC (August 2016). A symposium titled "Washing Your Produce--Sanitizing Solutions" was organized at the 2016 American Society for Horticultural Science Meeting in Atlanta, GA. How have the results been disseminated to communities of interest? Throughout the project, findings of research objectives have been disseminated through open access theses and dissertations, peer-reviewed journal publications, presentations in annual meetings of the Institute of Food Technologists, the American Institute of Chemical Engineers, the International Association of Food Protection, the American Society for Horticultural Science, and the OREI project directors' workshop, and the integrated extension activities. Through extension activities, project information was communicated with the Board of Advisors, field day participants that included organic and conventional growers, regulators, scientists, students and natural conservation officials, workshop participants, and free-access multi-media videos posted on YouTube and factsheets posted on the UT Extension website. A symposium titled "Washing Your Produce--Sanitizing Solutions" was delivered in the 2016 American Society for Horticultural Sciences annual meeting in Atlanta, GA, with the extension team presenting talks of "So Many Options, So Little Time: Selecting the Right Sanitizer for Your Operation," "Hitting the Mark for Food Safety and Organic Production in Postharvest," and "Filling the Pipeline: Considerations for Novel Sanitizers in Organic Production," followed by a panel discussion with speakers. 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 Objective 1, surfaces of spinach leaves were imaged, and contact angles of water droplets on cherry tomato, carrot, cantaloupe, lettuce leaf, and spinach leaf surfaces were determined and were reduced to $\sim 25^\circ$ by surfactants. For Salmonella on cherry tomatoes, gum arabic dissolved at 1% in 200 ppm chlorine solution lowered the decontamination efficacy. Studies on hydrophilic sanitizers were then focused on Citrox 14WP Pro Garda concentrate, an organically certified sanitizer in UK. A cocktail with five strains of Escherichia coli O157:H7 was inoculated on organic cherry tomatoes, baby spinach, Romaine lettuce, and cantaloupes, while a cocktail with five serovars of Salmonella enterica was inoculated on cherry tomatoes only. The inoculated samples were treated with aqueous solutions with 0.0%, 0.5%, and 0.75% v/v Citrox with and without 1.0% w/v organic load. Citrox treatments reduced pathogens up to 2 log more than the control and were similar to chlorine washes. Unlike chlorine, no transfer of bacteria to washing solutions and subsequent clean produce was observed for Citrox treatments that were also not significantly affected by the organic load. EPA approval is needed for use as a postharvest water sanitizing agent prior to utilization in the United States. In Objective 2, novel technologies of preparing plant essential oils (EOs) without specialized equipment such as a homogenizer were studied. Microemulsions using sucrose octanoate esters and lecithin had low loading of EOs. A technology was developed to readily prepare 1% EO emulsions using 1% whey protein concentrate, gum arabic, soybean lecithin, and their combinations by dissolving thyme oil, clove bud oil, or cinnamon oil in a hot alkaline solution and subsequently mixing with an aqueous emulsifier solution. Emulsions were prepared in several labs of the project team, demonstrating the ease and reproducibility of this technology. In tryptic soy broth, emulsions were generally similar to or more effective than free EOs in inhibiting bacteria. Emulsions with 0, 0.2, or 0.5% w/v EO were used to decontaminate Salmonella enterica, E. coli O157:H7 and Listeria monocytogenes five strain/serovar cocktails inoculated on organically grown cantaloupes, cherry tomatoes, baby spinach, Romaine lettuce, baby carrots, and snacking peppers with up to 5% organic load. The decontamination efficacy varied with the bacterial species and produce variety and was higher at a higher level of EOs. When emulsions with 0.5% EO were studied, bacteria on produce were reduced by ~ 1 to 3.5 log CFU/g, and the disinfection efficacy was less affected by organic load than chlorine. Similar to Citrox, EO emulsions prevented transferring of bacteria to wash solutions and uninoculated produce more effectively than chlorine and free EOs. The results show the potential use of emulsified EOs as alternative washes to decontaminate fresh produce and prevent cross-contamination. In Objective 3, field trials in 2015 were conducted for Romaine lettuce (cv. Cos) and tomatoes (Mountain Magic) in two fields at respective Universities' Organic Farms (1 in TN, 1 in NC). Field trials were repeated in 2016 for organic tomatoes (Mountain Magic) and yellow lunchbox snacking peppers (HMX-15637). Treatments included emulsions with 0.2% and 0.5% w/v thyme oil or clove bud oil, 0.5% and 0.75% Citrox, water (control), and 200 ppm chlorine wash. Aerobic plate counts and yeast and mold counts were determined on day 0 (immediately after wash), 3 and 7 under typical commercial storage conditions for lettuce and on day 0, 7, and 14 for tomatoes and peppers. Lettuce was determined to be incompatible for all EO emulsion treatments due to cell death and darkening. The EO emulsions behaved similarly to chlorine and Citrox behaved similarly to water when examining their interaction with the natural microflora of tomatoes. Overall appearance and firmness and shelf-life of tomatoes and peppers were similar after all treatments. Effects of alternative washing treatments on quality and sensory properties were studied in Objective 4. Emulsions with 0.5% thyme oil, clove bud oil, or cinnamon leaf oil were used to spray freshly harvested tomatoes and cantaloupes in 2015. After air-drying and storage at room temperature or at 4 °C, produce products were rated for browning, pitting, color development, and other changes every 3-7 days. Respiration and ethylene, total vitamin C, and pigments were determined with GC, HPLC, and spectrophotometry respectively. EO emulsions caused browning (possible cell necrosis) of lettuce

within 0 to 7 days at 4 °C. Cantaloupes treatments did not show significant differences in respiration and contents of ethylene, beta carotene, and vitamin C. The 'Mountain Magic' tomato cultivar was similar for all treatments, but the 'Mountain Belle' cultivar, a smaller cherry tomato, treated by cinnamon or clove bud oil emulsions developed visible differences during storage at 4 °C. In 2016, impacts on quality of produce were repeated for tomatoes and done on mini peppers (since lettuce did not respond well) after dipping in emulsions with 0.25 or 0.50% thyme oil or clove bud oil emulsified by gum arabic, water, or 200 ppm chlorine wash. Again, 'Mountain Magic' tomatoes after various treatments showed similar quality properties, with higher lycopene content ($P < 0.05$) for the thyme oil treatment. Mini peppers after the EO treatments had 3x higher ascorbic acid than other treatments. Malic and citric acid contents were also higher for the EO treatments, but this difference was not sustained over time. Sensory analysis was conducted in 2016 for organically grown tomatoes and snacking peppers harvested from Waynesville, NC and Knoxville, TN and repeated for grape tomatoes in 2017. Overall, appearance was not but flavor and aroma characteristics were affected by EO washes, which faded after storage at 13 °C for up to 6 days. These findings showed the barrier of EO aroma and flavor on acceptability of organic fresh produce post-washing. In Objective 5, the extension team determined the cost of EO emulsions was not able to be forecast as too many variables, such as decrease in cost of primary ingredients based upon commercial scale. Given the limited availability of pricing information that would reflect a commercialized product, a true cost-benefit analysis of alternative washing solutions was not possible. Three advisory board meetings were held throughout the duration of the project to inform the experimental design and extension activities as well as allow the group to report back on outcomes of the research. Collaborations from the research and extension teams have resulted in 1) a full day curriculum on safe postharvest washing of organic fruits and vegetables, 2) three videos published on the UT Good Agricultural Practices YouTube channel (Experimental Report Evaluating Essential Oils for Organic Wash Systems; Postharvest Basics; Postharvest Sanitizers for Organic Washing Systems), and 3) three factsheets. Eighty-nine individuals in the day-long workshops held in NC and TN increased their knowledge around food safety principles and practices for postharvest handling of organic fresh produce by 30.5%. The full curriculum is available to extension professionals in the United States. Factsheets were published on the University of Tennessee Extension: 1) How to Use and Monitor Chlorine in Fruit and Vegetable Washwater and on Equipment and Food Contact Surfaces (SP798-A.pdf), 2) Using Peroxyacetic Acid in Fruit and Vegetable Washing and Packing (SP798-B.pdf), and 3) Using Sanitizers on Organic Fruit and Vegetable Farms- Merging National Organic Program Guidelines with Good Agricultural Practices (SP798-C.pdf). The availability of these multi-media materials to the public will have a long-term impact on enhancing the microbial safety of organic fresh produce. Publications Type: Journal Articles Status: Published Year Published: 2014 Citation: Zhang, L., F. Critzer, P.M. Davidson, and Q. Zhong. 2014. Formulating essential oil microemulsions as washing solutions for organic fresh produce production. *Food Chemistry*. 165: 113118. Type: Journal Articles Status: Published Year Published: 2014 Citation: Luo, Y., Y. Zhang, K. Pan, F. Critzer, P.M. Davidson, and Q. Zhong. 2014. Self-emulsification of alkaline-dissolved clove bud oil by whey protein, gum arabic, lecithin, and their combinations. *Journal of Agricultural and Food Chemistry*. 62(19): 44174424. Type: Journal Articles Status: Published Year Published: 2016 Citation: Zhang, Y., Q. Ma, F. Critzer, P.M. Davidson, and Q. Zhong. 2016. Organic thyme oil emulsion as an alternative washing solution to enhance the microbial safety of organic cantaloupes. *Food Control*. 67: 31-38. Type: Journal Articles Status: Published Year Published: 2017 Citation: Zhang, Y., H. Chen, F. Critzer, P.M. Davidson, and Q. Zhong. 2017. Potential of cinnamon oil emulsions as alternative washing solutions of carrots. *Journal of Food Protection*. 80(6): 9941001. Type: Journal Articles Status: Published Year Published: 2017 Citation: Jiang, C., P. Perkins-Veazie, G. Ma, and C. Gunter. 2017. Muskmelon Fruit Quality in Response to Postharvest Essential Oil and Whey Protein Sprays. *Horticultural Science* 52:887-891. Type: Theses/Dissertations Status: Published Year Published: 2015 Citation: Harness III, M.L. 2015. Sanitization Effectiveness of Alkaline-Dissolved Essential Oils as Organic Produce Washing Solutions. MS thesis, University of Tennessee - Knoxville. Type: Theses/Dissertations Status: Published Year Published: 2015 Citation: Simmons, E.R. 2015. Evaluation of a natural antimicrobial-based sanitizer as an alternative to chlorine for reducing foodborne pathogenic bacteria on organic produce. MS thesis, University of Tennessee - Knoxville. Type: Theses/Dissertations Status: Published Year Published: 2016 Citation: Jiang, C. 2016. Postharvest quality of vegetables after application of essential oils as innovative sanitizers. PhD Dissertation, North Carolina State University. Type: Theses/Dissertations Status: Awaiting Publication Year Published: 2017 Citation: Dunn, L. 2017. A Transcriptomic Analysis of *Salmonella enterica* Newport In Planta and after Postharvest Sanitization. PhD Dissertation, University of Tennessee-Knoxville. Type: Conference Papers and Presentations Status: Published Year Published: 2013 Citation: Zhang, L., F.M. Critzer, P.M. Davidson, and Q. Zhong. 2013. Formulation of essential oil microemulsions to enhance the microbial safety of organic fresh produce. The 2013 IFT Annual Meeting, July 13-16, Chicago, IL. Paper #255-168. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Luo, Y., Y. Zhang, K. Pan, F. Critzer, P.M. Davidson, and Q. Zhong. 2014. Self-emulsification of alkaline-dissolved clove bud oil by whey protein, gum arabic, lecithin, and their combinations. The 2014 AIChE Annual Meeting, Nov. 16-21, Atlanta, GA. Paper 364033. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Zhang,

Y., F. Critzer, P.M. Davidson, and Q. Zhong. 2014. Application of self-emulsified organic thyme oil as washing solution to enhance the microbial safety of cantaloupes. The 2014 NIFA Organic Programs Project Directors Meeting, Oct. 21-22, Washington, DC. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Zhang, Y., F. Critzer, P.M. Davidson, and Q. Zhong. 2015. Organic thyme oil emulsion as an alternative washing solution to enhance the microbial safety of organic cantaloupes. The 2015 IFT Annual Meeting, July 11-14, Chicago, IL. Paper # 125-076. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Gann, L., M. Harness, P.M. Davidson, Q. Zhong, and F. Critzer. 2015. Utilization of Emulsified clove bud oil and thyme oil to inactivate Salmonella on cherry tomatoes and Escherichia coli O157:H7 on baby spinach. The 2015 Annual Meeting of the International Association for Food Protection, July 25-28, Portland, OR. Paper #P3-210. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Simmons, E., F. Critzer, Q. Zhong and P.M. Davidson. 2015. Efficacy of a commercial antimicrobial agent on organic produce against Escherichia coli O157:H7 and Salmonella enterica. The 2015 Annual Meeting of the International Association for Food Protection, July 25-28, Portland, OR. Paper #P3-116. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Jiang, C., and P. Perkins-Veazie. 2015. Postharvest quality of leafy green crops with essential oil application-a natural antimicrobial for food safety. The 2015 Annual Meeting of the American Society for Horticultural Science. Aug. 2-7, New Orleans, LA. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Jiang, C., P. Perkins-Veazie, C. Gunter, L. Quesada, E. Gutierrez. 2015. Essential oils as a chlorine alternative for produce safety: Effects on postharvest quality of cherry tomatoes. HortScience 51:S105. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Perkins-Veazie, P., Gorman, S., Davis, J., Ducharme, D., Wszelaki, A., Critzer, F. 2016. Essential oil disinfectant on appearance and composition of organically grown tomatoes HortScience 52:S250. Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Dunn, L., M. Harness, D. Smith, S. Gorman, A. Hamilton, P.M. Davidson, Q. Zhong, and F. Critzer. 2017. Essential oil nanoemulsions as post-harvest wash solutions on snacking peppers. The 2017 Annual Meeting of the International Association for Food Protection, July 9-12, Tampa, FL. Paper #P1-198. Type: Conference Papers and Presentations Status: Published Year Published: 2017 Citation: Zhang, Y., H. Chen, F. Critzer, P.M. Davidson, and Q. Zhong. 2017. Application of self-emulsified cinnamon oil as washing solution to enhance the microbial safety of baby carrots. The 2017 IFT Annual Meeting & Food Expo, June 25-28, Las Vegas, NV. Paper #P06-052. Progress 09/01/15 to 08/31/16 Outputs Target Audience:Organic and conventional growers, regulators, scientists, students and natural conservation officials. Changes/Problems:No major changes are expected. We expect to complete research and extension objectives after being given one-year no-cost extension. What opportunities for training and professional development has the project provided?The project thus far has trained 2 MS and 1 PhD students on produce microbiological safety, 1 PhD student on fresh produce quality, 2 MS students and 4 post-doctoral students on produce surface properties and essential oil emulsions. Three post-doctoral students involved in the project have now taken assistant professor positions in research universities in the USA. Additionally, a series of field presentations (Field Days) allowed for practical information to be presented to various audiences that include organic and conventional growers, regulators, scientists, students and natural conservation officials. Alternative Crops and Organics Field Tour, Mountain Horticultural Crops, Waynesville, NC. August 2015 (85 participants) Organic Field Day, Mountain Horticultural Crops, Waynesville, NC. August 2016 (105 participants) Mountain Horticultural Crops Research Station Field Days, Waynesville, NC. July 2016 (201 participants) Tomato Field Day, Mountain Horticultural Crops Research and Extension Center, Mills River, NC. August 2016. How have the results been disseminated to communities of interest?In the past year, we presented our research findings in the 2016 American Society for Horticultural Sciences annual meeting in Atlanta, GA (August 16-18). During this meeting a symposium with three talks (outlined below) and one poster presentation titled \"Essential Oil Disinfectant on Appearance and Composition of Organically Grown Tomatoes\" were shared. The symposium titled \"Washing Your Produce--Sanitizing Solutions\" was led by four speakers from our Extension team: 1. So Many Options, So Little Time: Selecting the Right Sanitizer for Your Operation-Diane Ducharme, North Carolina State University 2. Hitting the Mark for Food Safety and Organic Production in Postharvest- Annette Wszelaki, University of Tennessee 3. Filling the Pipeline: Considerations for Novel Sanitizers in Organic Production- Laurel Dunn, University of Tennessee 4. Panel Discussion with Speakers - Diane Ducharme, Annette Wszelaki, and Laurel Dunn In addition, one refereed research article, 1 PhD dissertation, and two MS theses have been published. What do you plan to do during the next reporting period to accomplish the goals?In the next reporting period, field trials will be adjusted to use tomatoes and peppers, rather than tomatoes and lettuce, due to the poor response of lettuce to essential oils. Composition of treated and stored fruit is finishing up with data analysis from both growing seasons (tomatoes) and single growing seasons (lettuce and peppers) taking priority in the coming year. Impacts What was accomplished under these goals? In the fourth project year, research objectives have been mostly completed. The efforts in the first and second objectives have been focused on disseminating results, with a paper published and others getting ready for submission. In Objective 3, the 2nd year of field trials continued with two fields at respective Universities (1 in TN, 1 in NC) with two crops of organic tomatoes (Mountain Spring)

and peppers (yellow Lunchbox snack peppers from Johnny's Selected Seeds). Snacking peppers were substituted for Romaine lettuce, which was shown to be unmarketable through work in Objective 4 in the first year of field trials. Tomatoes and snacking peppers were exposed to wash solutions consisting of emulsified thyme oil and clove bud oil as well as Citrox and were compared to control treatments of water and 200 ppm chlorine wash for their applicability in the field setting. Produce was sampled at day 0 (immediately after treatment), 7, and 14 from each location. Microbiological data analysis is still on-going, but indicates that the performance of emulsified essential oils is similar if not better than that of 200 ppm chlorine and better than water alone in reducing populations of yeast, molds, and bacteria that cause spoilage for both tomatoes and peppers on day 0. However, these populations were similar across all treatments by day 14. In the fourth objective, tomatoes and snacking peppers were exposed to the alternative wash solutions as well as the water and chlorine controls. Generally, 'Mountain Magic' tomatoes treated with essential oils had few changes compared to water or chlorine. Total lycopene content was highest at all storage days in tomato fruit treated with thyme oil. Total phenolic content decreased over storage time for most treatments but was slightly higher in tomatoes treated with thyme oil. Analysis of lettuce indicated a loss of total phenolic and chlorophyll content in those treated with cinnamon or clove oil, which is consistent with the immediate browning reaction (possible cell necrosis) of lettuce to essential oils. In control (water, chlorine) treatments, total phenolic content increased with storage time. Sensory Studies started with July & August 2016 harvests from Waynesville, NC and Knoxville, TN. Descriptive sensory analysis with 100 panelists was conducted for peppers and tomatoes utilizing emulsified thyme, clove bud, and cinnamon oil in addition to Citrox and the controls of water or chlorine. Sensory testing occurred 18-24 hr after washes were applied and demonstrated that all alternative washes were liked similarly to chlorine and water controls with respect to appearance. However the emulsified essential oils were liked less than the water and chlorine controls with respect to the following parameters: overall liking, flavor liking, texture liking, and freshness intensity. Based on this feedback, we recommend conducting sensory testing at intervals past 18hr post-wash to see if these same results hold true since it is unlikely that any produce would be consumed this soon after washing given typical distribution channels. Educational development: The TN and NC Extension Team meet with the Advisory Board members in late February 2016 to provide updates on progress of research and extension efforts and to ask for assistance in getting into existing venues for outreach activities. The Extension team continues communication efforts through out the year with 2-hr. conference calls to further development of resources. Seven modules for delivery of curriculum continue development activities. Learning objectives have been reviewed and accepted by all team members as well as a template being developed for modules. Modules have been developed and been delivered in several existing venues (see below). Several conference presentation requests had been made without success; additional requests have been made for the upcoming fall/winter meetings. The project was highlighted in North Carolina on Dr. Davis's blog and during the August 20 Alternative Crops and Organics Field Tour. During this event, progress on the project was shared with many visitors to the field including scientists, students, and growers. Extension factsheets are developed on the use of organic sanitizers (PAA), postharvest care, and use of sanitizers approved for NOP and how to use chlorine effectively. Factsheets are currently under peer review and will be submitted to University for publication. A private videographer was secured to develop 3 short educational videos. Scripts were written, recommendations for photographic shots to capture visual content, and peer review of content was completed by late fall. Video shots were staged at a local packinghouse during the 3rd week of March 2016. Drafts of videography are currently in review by Extension team. Three titles include: 1) Postharvest Sanitizers for Organic Wash Systems; 2) Fresh Produce Postharvest Basics; 3) Evaluating Essential Oils for Organic Wash Systems. These videos will be used in the workshops, posted on the website (<https://ncfreshproducesafety.ces.ncsu.edu/>) as well as have the potential to be extended to an eXtension webinar. Finally, a 12 question survey was sent to organic growers on the following topics: good agricultural practices (GAP) implementation, produce washing procedures, commodities washed, wash quality, type of sanitizers used and where used, and interest in essential oils that could reduce the risk of foodborne pathogens. Results from survey will be used to build an Excel-based interactive tool comparing each alternative to chlorine and the costs associated with that decision is being developed for deployment in fall 2016. Publications Type: Journal Articles Status: Published Year Published: 2016 Citation: Zhang, Y., Q. Ma, F. Critzer, P.M. Davidson, and Q. Zhong. 2016. Organic thyme oil emulsion as an alternative washing solution to enhance the microbial safety of organic cantaloupes. *Food Control*. 67: 31-38. Type: Theses/Dissertations Status: Published Year Published: 2016 Citation: Jiang, C. 2016. Postharvest quality of vegetables after application of essential oils as innovative sanitizers. PhD Dissertation, North Carolina State University. Type: Theses/Dissertations Status: Published Year Published: 2015 Citation: Harness III, M.L. 2015. Sanitization Effectiveness of Alkaline-Dissolved Essential Oils as Organic Produce Washing Solutions. MS thesis, University of Tennessee - Knoxville. Type: Theses/Dissertations Status: Published Year Published: 2015 Citation: Simmons, E.R. 2015. Evaluation of a natural antimicrobial-based sanitizer as an alternative to chlorine for reducing foodborne pathogenic bacteria on organic produce. MS thesis, University of Tennessee - Knoxville. Progress 09/01/14 to 08/31/15 Outputs Target Audience: Scientific community and produce industry. Changes/Problems: Nothing Reported What opportunities for training and professional development has the

project provided? The project has trained 2 MS and 1 PhD students on produce microbiological safety, 1 PhD student on fresh produce quality, 2 MS students and 2 post-doctoral students on produce surface properties and essential oil emulsions. Two post-doctoral students involved in the project have now taken assistant professor positions in two major research universities. How have the results been disseminated to communities of interest? In the past year, we presented our research findings in the 2015 Annual Meetings of the Institute of Food Technologists in Chicago, IL (one poster) and the International Association of Food Protection in Portland, OR (two posters) and at the 2015 Annual Meeting of the American Society for Horticultural Science (one poster). We invited members of our Board of Advisors to attend our project annual meeting in Waynesville, NC and received valuable feedbacks on our research findings and extension plans. What do you plan to do during the next reporting period to accomplish the goals? In the next reporting period, we plan to repeat field trials (Objective 3). We will continue Objective 5 (cost analysis) and other extension activities as proposed. Impacts What was accomplished under these goals? In the third project year, the proposed research objectives were being further progressed. In the first objective, a commercial citrus-based natural antimicrobial, Citrox, was also evaluated for its efficacy in rinse water to inactivate five-strain cocktails of *Escherichia coli* O157:H7 or *Salmonella enterica* on cantaloupes, as well as *Listeria monocytogenes* on either organically grown cherry tomatoes, baby spinach, Romaine lettuce, or cantaloupes. Studies on the transfer of bacteria to rinse water and clean produce were completed for the three bacteria and the four produce products. Results from the past reporting period confirmed that (1) Citrox was an effective inhibitor of the Gram negative and Gram positive bacteria and (2) Citrox sanitizing solutions stopped transfer, or cross contamination, from inoculated produce to un-inoculated produce when tested at 0.5% and 0.75%. The absence of cross-contamination is beneficial in large-scale distribution of organic produce since all the tomatoes, leafy greens and cantaloupes will share one large dump tank during post-harvest processing. Citrox contains organic compounds so using it as a sanitizing agent on organic produce allows the produce to remain organic. In the second objective, we completed studies on essential oils self-emulsified by whey protein concentrate (WPC), gum arabic, or their combination as alternative washing solutions to reduce pathogens on organically grown produce by expanding produce varieties to baby spinach, baby carrots, and green onions. Continuing from the last reporting period, the recovery of *Salmonella* and *L. monocytogenes* cocktails on whole cantaloupes after washing by 0.2% free or emulsified thyme oil (TO) was studied during the subsequent ambient (21 °C) storage for up to 14 days. The populations of *Salmonella* and *L. monocytogenes* reduced in all treatments during storage, and were consistently the lowest after washing by the TO emulsion and storage up to 10 days, while no significant difference between free and emulsified TO treatments was observed on day 14. For baby carrots inoculated with *Salmonella*, *E. coli* O157:H7, or *L. monocytogenes*, cinnamon oil (CO, with the major component being eugenol) emulsified by gum arabic or the combination of WPC and gum arabic was studied at 0.2% or 0.5%, which was compared to rinsing with water only or the same concentration of free CO. The reduction of bacteria on baby carrots was generally more effective at 0.5% CO than at 0.2% CO, and the emulsified CO was slightly (~0.5 log CFU/m²) more effective than free CO. 0.5% emulsified CO eliminated cross-contamination and was not affected by 2% and 5% organic loads (OLs). Similarly, 0.5% emulsified CO was more effective than free CO for green onions inoculated with pathogens but caused tissue damages. Without OL, chlorine at 200 ppm was the most effective with over a 4 log reduction of *E. coli* O157:H7 on baby spinach compared to emulsified TO and clove bud oil (CBO). However, 0.5% (v/v) TO was the second most effective, with a 3 log reduction of *E. coli* O157:H7, and seemed completely invulnerable to OL while chlorine with 1% OL was significantly less effective than all emulsified TO. Results from testing for *E. coli* O157:H7 transfer were much the same, with chlorine being the most effective but significantly hindered by the presence of organic matter. The results to date indicate potential of emulsified essential oils for use as post-harvest rinses for fresh produce, as they consistently showed more resilience against OL than chlorine. In Objective 3, field trials commenced for Romaine lettuce and tomatoes. Wash solutions consisting of emulsified TO and CBO as well as Citrox were compared to a water and 200ppm chlorine wash. Lettuce were sampled on day 0 (immediately after wash), 3 and 7 under typical commercial storage conditions for aerobic plate counts (APC) and yeast and mold (YM) counts, while tomatoes were sampled on day 0, 7, and 14. Similar populations for all wash treatments were observed on YM and APC and increased similarly throughout the 7 day holding period for lettuce. Our alternative wash solutions did not result in any different bacterial populations than chlorine or water only treatments which are more commonly used amongst small and medium organic growers to prepare produce for market. Data collection is just being completed for tomatoes. All field trials will be replicated once more during the next growing season. In the fourth objective, essential oil formulations were tested on field lettuce and tomatoes. Organically grown romaine lettuce from Waynesville, NC was harvested, cooled, and shipped to Knoxville TN or to Kannapolis NC. Lettuce were dipped in formulations of 0.25 or 0.50% CO or CBO emulsified by gum arabic or in 200 ppm chlorine or water, drained, and held at 4 C for 3 to 10 days. Heads were weighed and rated at days 3, 7, and 10 and green color determined at the leaf apex. CO and CBO treatments had negative effects on quality, causing browning that appeared within 0 to 7 days depending on percent oil. Tomatoes were dipped in oil formulations of the same concentration and are currently being evaluated. Additionally, similar effects of essential oils on lettuce were observed for freshly harvested and store-bought

Romaine lettuce. An attempt to further explain this phenomenon is being undertaken at a more cellular level. Extension activities have been initiated in the third project year. Starting in January, an Advisory Board Meeting was held to provide updates on the alternative organic antimicrobials, discussion on results and introduction of the field and Extension portions of this project. Field Studies: For the field testing of the alternative antimicrobial washes, two fields have been secured at respective Universities (1 in TN, 1 in NC) with two crops (Cherry tomato 'Mountain Magic' and Romaine lettuce 'Parris Island Cos'). Organic seeds were grown in greenhouses (February - March) and transplanted to organic certified fields in spring 2015 (April - May). Romaine lettuce were harvested two times (end of April - May) and tomatoes harvested one time (July). These products were used in field studies as detailed above and assessed for shelf-life (weight and color assessments). Educational development: Extension efforts centered on economic feasibility, workshop and resource development, and video/still photography capture. An economic feasibility to capture costs associated with existing antimicrobials used within the fruit and vegetable industry (chlorine and PAA), as well as any viable alternative with costs acquired. A survey is being developed to capture specifics on uses/costs and a webinar is to be developed as well as workshop content. Brainstorms on workshop content, locations and venues were done with internal committee as well as Advisory Board; several existing shorter venues (30 min. - 1 hr.) were applied to for workshop delivery (2016). An agenda for a day workshop with assignments to committee members for the development of learning modules, identification of resource needs, hands-on activities, and methods of evaluation are currently in place. Resource materials defined include hands-on activities and ordering of materials, factsheet development, Webinar, and videos. Video/still photography was captured for both the field and laboratory experiments and will be incorporated into the delivery of workshops. Additionally, a "grower's kit" will be utilized and given to participants at the workshops. Publications Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Zhang, Y., F. Critzer, P.M. Davidson, and Q. Zhong. 2015. Organic thyme oil emulsion as an alternative washing solution to enhance the microbial safety of organic cantaloupes. The 2015 IFT Annual Meeting, July 11-14, Chicago, IL. Paper #125-076. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Gann, L., M. Harness, P.M. Davidson, Q. Zhong, and F. Critzer. 2015. Utilization of Emulsified clove bud oil and thyme oil to inactivate Salmonella on cherry tomatoes and Escherichia coli O157:H7 on baby spinach. The 2015 Annual Meeting of the International Association for Food Protection, July 25-28, Portland, OR. Paper #P3-210. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Simmons, E., F. Critzer, Q. Zhong and P.M. Davidson. 2015. Efficacy of a commercial antimicrobial agent on organic produce against Escherichia coli O157:H7 and Salmonella enterica. The 2015 Annual Meeting of the International Association for Food Protection, July 25-28, Portland, OR. Paper #P3-116. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Jiang, C., and P. Perkins-Veazie. 2015. Postharvest quality of leafy green crops with essential oil application-a natural antimicrobial for food safety. The 2015 Annual Meeting of the American Society for Horticultural Science. Aug. 2-7, New Orleans, LA.

PROGRESS

2013/09 TO 2014/08 Target Audience: Scientific community. Changes/Problems: No changes. What opportunities for training and professional development has the project provided? Trained 2 MS and 1 PhD students on produce microbiological safety, 1 PhD student on fresh produce quality, 2 MS students and 2 post-doctoral students on produce surface property and essential oil emulsions. One post-doctoral student is now on faculty in a major research university. How have the results been disseminated to communities of interest? In the past year, we gave an oral presentation about self-emulsification technology at the 2014 Annual Meeting of the American Institute of Chemical Engineers (Atlanta, GA) and a poster presentation at the OREI project directors' workshop (Washington, DC). We also published two research articles based on findings in the past two years. What do you plan to do during the next reporting period to accomplish the goals? In the next reporting period, we will continue to study research Objectives 1, 2 and 4 to identify formulations that are effective in inactivating *Listeria monocytogenes*, *Escherichia coli* O157:H7, and *Salmonella* on organic produce and cause minimal quality defects. The identified formulations will be used for Objective 3 for field trials and Objective 5 for cost analysis in years 3 & 4. We will also begin extension activities as proposed.

2012/09 TO 2013/08 Target Audience: Scientific community. Changes/Problems: No changes. What opportunities for training and professional development has the project provided? Trained 1 MS and 2 PhD students on produce microbiological safety, 1 PhD student on fresh produce quality, 1 MS student and 1 post-doctoral student on produce surface property and essential oil emulsions. How have the results been disseminated to communities of interest? A poster presentation about formulating microemulsions of essential oils was given at the 2013 Annual Meeting of the Institute of Food Technologists (Chicago, IL). What do you plan to do during the next reporting period to accomplish the goals? In the next reporting period, we will continue to

study research Objectives 1 and 2, focusing on microbiological experiments to identify formulations effectively inactivate *Listeria monocytogenes*, *Escherichia coli* O157:H7, and *Salmonella* on organic produce. The findings will be used for Objectives 3 and 4 in years 3 & 4. We will also begin planning extension activities and field trials to take place in years 3 & 4.

IMPACT

2013/09 TO 2014/08 What was accomplished under these goals? In the current reporting period, we continued to study the proposed research objectives and planned extension activities to be initiated next year. For the first objective, because we found the ineffectiveness of chlorine in reducing bacteria on cherry tomatoes with the presence of organic matter, we studied an alternative aqueous sanitizer, Citrox 14WP Pro Garda concentrate that is an organically certified sanitizer in UK. The efficacy of Citrox in inhibiting foodborne pathogens on organic cherry tomatoes, baby spinach, and romaine lettuce and the prevention of cross-contamination were studied. The foodborne pathogens were cocktails of five strains of *Escherichia coli* O157:H7 or five serovars of *Salmonella enterica* (on cherry tomatoes only). The Citrox was tested at 0.0% (control), 0.5%, and 0.75% v/v in aqueous solutions, with and without 1.0% w/v organic load. The reduction of bacteria by Citrox was up to 2 log lower than the control. The transfer of bacteria to washing solution and subsequent clean produce was significant for the control but not detected for Citrox treatments. The organic load had no significant effect on Citrox treatments. For the second objective, we continued to study the novel technology developed in the previous year that self-emulsifies essential oils using whey protein concentrate 34 (WPC-34), gum arabic, soybean lecithin, and their combinations as emulsifiers. We have characterized structure and stability of emulsions prepared from clove bud oil (CBO), thyme oil, cinnamon oil, and vanilla oil and the minimum inhibitory (MIC) and bactericidal concentrations (MBC) of these emulsions against cocktails/serovars of *Salmonella enterica*, *Escherichia coli* O157:H7 and *Listeria monocytogenes*. Vanilla extract and pure vanilla were ineffective against these pathogens. The MIC and MBC of thyme oil were the lowest among the essential oils, followed by CBO. Based on the physical stability and antimicrobial activity, one emulsion each of thyme oil and CBO was chosen as alternative washing solutions. Thyme oil self-emulsified with gum arabic was compared with free thyme oil dissolved in 5% ethanol for their antimicrobial activities against *Salmonella enterica*, *Escherichia coli* O157:H7 and *Listeria monocytogenes* inoculated on organically grown cantaloupes. After treatment by 0.1%, 0.2%, 0.5% emulsified or free thyme oil for 2 min, the emulsified thyme oil exhibited significantly better inhibition against the three bacteria than free thyme oil. The efficacy of thyme oil at different organic loads (2% and 5%) was also evaluated. The organic load showed no effects on the antimicrobial efficacy of emulsified thyme oil but a slight improvement on the inhibition activity of free thyme oil. Thyme oil (0.2% and 0.5%) self-emulsified with gum arabic, CBO (0.2% and 0.5%) self-emulsified with WPC-34, and CBO (0.2% and 0.5%) self-emulsified with WPC-34 and gum arabic combination were tested against *Salmonella* serovars on the surfaces of cherry tomatoes and compared to the efficacy of chlorine at 200 ppm. 0.5% CBO self-emulsified with WPC-34 and WPC-34/gum arabic combination showed a significantly greater reduction than chlorine at 200 ppm. These emulsions were significantly less effective in the presence of 1% organic load but were still as effective as the chlorine treatment. 0.5% thyme oil emulsified with gum arabic was just as effective as chlorine at 200 ppm and showed no significant difference in the presence of 1% organic load. Overall, 0.5% CBO emulsified with WPC-34 was the most effective at reducing levels of *Salmonella* on cherry tomato surfaces, while 0.5% thyme oil emulsified with gum arabic was the least susceptible to the presence of organic compounds. For the fourth objective, effects of essential oil emulsions on postharvest quality and shelf life of cherry tomato, cantaloupe, and Romaine lettuce were evaluated. Emulsions of thyme oil, CBO, and cinnamon leaf oil were prepared with WPC-34, adjusted to pH 6.5, and diluted with water to a final oil concentration of 0.5%. Freshly harvested tomatoes and cantaloupes were sprayed with the emulsions, air-dried, and stored at room temperature or at 4 °C. Subjective ratings for browning, pitting, color development, and other changes were made every 3-7 days. Respiration and ethylene were measured by GC and total vitamin C assayed by HPLC. Pigment content (mostly beta carotene in cantaloupe and lycopene in tomatoes) was assayed by hexane extraction and absorbance at 450 and 503 nm by spectrophotometry. In cantaloupe, some brown spotting was found, but least with the thyme oil emulsion. No differences in respiration, ethylene content, beta carotene, or vitamin C content were found among treatments. In tomato, two cultivars were used. 'Mountain Magic' had no adverse symptoms and no differences were found among treatments for assays of color, ratings, respiration, or vitamin C. 'Mountain Belle', a smaller cherry tomato, showed some pitting and delayed color development when held at 4 C following treatment with cinnamon or clove oil emulsions.

PUBLICATIONS (not previously reported): 2013/09 TO 2014/08 1. Type: Journal Articles Status: Published Year Published: 2014 Citation: Zhang, L., F. Critzer, P.M. Davidson, and Q. Zhong. 2014. Formulating essential oil microemulsions as washing solutions for organic fresh produce production. *Food Chemistry*. 165: 113-118. 2. Type: Journal Articles Status: Published Year Published: 2014 Citation: Luo, Y., Y. Zhang, K. Pan, F. Critzer,

P.M. Davidson, and Q. Zhong. 2014. Self-emulsification of alkaline-dissolved clove bud oil by whey protein, gum arabic, lecithin, and their combinations. *Journal of Agricultural and Food Chemistry*. 62(19): 4417-4424. 3. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Luo, Y., Y. Zhang, K. Pan, F. Critzer, P.M. Davidson, and Q. Zhong. 2014. Self-emulsification of alkaline-dissolved clove bud oil by whey protein, gum arabic, lecithin, and their combinations. The 2014 AIChE Annual Meeting, Nov. 16-21, Atlanta, GA. Paper 364033. 4. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Zhang, Y., F. Critzer, P.M. Davidson, and Q. Zhong. 2014. Application of self-emulsified organic thyme oil as washing solution to enhance the microbial safety of cantaloupes. The 2014 NIFA Organic Programs Project Directors Meeting, Oct. 21-22, Washington, DC.

2012/09 TO 2013/08 What was accomplished under these goals? In the current reporting period, we had our first Board of Directors (BOA) meeting on February 12, 2013. For the first objective, we evaluated the ability of surfactants to improve the interaction of chlorine with target microorganisms when *Salmonella* was inoculated onto cherry tomatoes. The recovered *Salmonella*, 7.19 log CFU/20g sample, was similar for the untreated group, those dipped into a wash liquid containing only deionized water or 200 ppm chlorine and 1% gum arabic ($P > 0.05$). The recovered *Salmonella* was significantly reduced ($P < 0.05$) when dipped in 200 ppm chlorine and 0.1% gum arabic or only 200 ppm chlorine, corresponding to 5.66 or 4.96 log CFU/20g sample, respectively. In addition, samples that followed the washing treatments of contaminated tomatoes were analyzed to test for the amount of *Salmonella* transferring onto clean tomatoes. Water was the least effective of these with an average of 4.57 log CFU/20g *Salmonella* transferred. All chlorinated treatment washes were similarly effective at preventing the transfer of *Salmonella*, with numbers from 1.08 (chlorine + 0.1% gum arabic) to 1.24 (chlorine) up to 1.53 (chlorine + 1% gum arabic) log CFU/20g sample. For the second objective, we continued to study formulations using sucrose octanoate esters (SucraShield®) and lecithin to dissolve essential oils. Surface tension on four produce products - cherry tomato, carrot, cantaloupe, lettuce leaf, and spinach leaf was significantly reduced by the microemulsion with dissolved essential oils when compared to deionized water. Because SucraShield may be too expensive for practical applications, we studied another method to self-emulsify essential oils using whey protein concentrate 34 (WPC-34), gum arabic, soybean lecithin, and their combinations as emulsifiers. This was enabled by the deprotonation under alkaline conditions to dissolve essential oils, addition of emulsifier(s), and neutralization. Deprotonation conditions were optimized for the capacity to produce stable essential oil emulsions after self-emulsification. Physicochemical properties, including particle size, entrapment efficiency, stability, and particle morphology of emulsions were characterized. Several essential oils were tested, and clove bud oil was found to be the most suitable for this self-emulsification technique. WPC and equal mass of WPC and gum arabic were the most feasible emulsifiers, showing 1% biopolymer capable of emulsifying 1% clove bud oil and no significant changes in mean particle dimension during 7-day storage at ambient conditions. Based on high performance liquid chromatography, the major component of clove bud oil, eugenol, showed a similar elution profile before and after self-emulsification. When tested against *Listeria monocytogenes* Scott A, *Escherichia coli* O157:H7 ATCC 43895 and *Salmonella* Enteritidis, the emulsions showed similar or lower minimum inhibitory (MIC) and bactericidal concentrations (MBC) than clove bud oil dissolved in ethanol. Similar observations were found when emulsions and free oils were studied for growth kinetics of bacteria in tryptic soy broth. For the fourth objective, postharvest rating systems for cherry tomato, Romaine lettuce, and cantaloupe were developed to follow subjective changes during storage after application of developed products, and criteria for bioactives of interest were established. **PUBLICATIONS (not previously reported):** 2012/09 TO 2013/08 Type: Conference Papers and Presentations Status: Published Year Published: 2013 Citation: Zhang, L., F.M. Critzer, P.M. Davidson, and Q. Zhong. 2013. Formulation of essential oil microemulsions to enhance the microbial safety of organic fresh produce. The 2013 IFT Annual Meeting, July 13-16, Chicago, IL. Paper #255-168.

[↑ Return to Index](#)

Developing Adapted Varieties and Optimal Management Practices for Quinoa in Diverse Environments

Accession No.	0230469
Subfile	CRIS
Project No.	WNP03105
Agency	NIFA WN.P
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2012-51300-20100
Proposal No.	2012-02270
Start Date	01 SEP 2012
Term Date	31 AUG 2016
Grant Amount	\$1,603,653
Grant Year	2012
Investigator(s)	Murphy, K. M.; Baik, B.; Benedict, C.; Creech, E.; Desta, K.; Goldberger, J.; Machado, S.; Maughan, J.; Matanguihan, J.; Petrie, S.; Reeve, J.
Performing Institution	Crop & Soil Sciences, WASHINGTON STATE UNIVERSITY, PULLMAN, WASHINGTON 99164

NON-TECHNICAL SUMMARY

Quinoa is a broadly adapted grain crop in huge demand in the US because it is highly nutritious, with excellent protein quality and quantity. The current organic quinoa supply from the quinoa producing Andean countries is insufficient to meet the existing and growing demand in the US, driving distributors, wholesalers, and retailers to seek out domestic, reliable sources of quinoa. Domestic supply is essentially nonexistent for several reasons, primarily due to the lack of information regarding regionally adapted varieties, best management practices for organic farms, or marketing options for quinoa. This project will provide the information urgently needed by farmers wanting to capitalize on the rapidly expanding quinoa market. Organic growers and quinoa distributors have been instrumental in the development of all stages of this proposal. Our goals are to 1) identify and quantify domestic demand and future marketing opportunities for domestically grown organic quinoa; 2) evaluate and select quinoa varieties and breeding lines in organic systems for critical traits of interest; 3) develop best management practices for organic quinoa production; 4) evaluate the end-use quality traits and nutritional value of quinoa varieties and breeding lines; and 5) disseminate information about, and develop farmer/distributor relationships for, organic quinoa production and marketing. A Stakeholder Advisory Committee has been formed, consisting of representative growers, wholesalers, retailers, and end-users. The results of the project will contribute to OREIs legislatively-defined goals 1, 2, 6, 7 and 8 by generating research information and educating different clientele on quinoa production and marketing.

OBJECTIVES

The overall, long-term goals of this project are to: 1) quantify the current demand and the market potential for US-grown organic quinoa; 2) select quinoa varieties adapted to organic systems through further development of the WSU quinoa breeding program and through variety testing in Washington, Oregon, and Utah; 3) evaluate and develop best management practices to optimize organic quinoa production systems; and, 4) disseminate information to diverse audiences using a range of outreach methods. The primary stakeholders of this project

include organic growers, and current quinoa distributors, wholesalers, and retailers. Critical needs described by growers at roundtables, field days and in phone conversations and email communications include: 1) the development of varieties adapted to their region and to organic farming, 2) the identification of best management practices for quinoa production, and 3) the development of new marketing channels for growers. Critical needs outlined by growers include heat, drought, and salinity tolerant varieties; saponin-free, highly nutritious varieties; intercropping options; optimal nitrogen fertility regimes; seeding rates and dates; irrigation requirements and timing; and marketing options. Growers emphasized repeatedly that none of these critical needs were being met at present. Research (1-4) and Extension (5) Objectives 1. Identify and quantify demand and future marketing opportunities for domestically grown organic quinoa 2. Evaluate and select quinoa varieties and breeding lines in organic systems for critical traits of interest 3. Develop best management practices for organic quinoa production 4. Evaluate the end-use quality traits and nutritional value of quinoa varieties and breeding lines 5. Disseminate information about, and develop farmer/distributor relationships for, organic quinoa production and marketing

There is currently very little known about locally adapted quinoa varieties and even less about agronomic and best management practices for quinoa production in the US. The most immediate impact will be a significant increase in knowledge regarding varieties of quinoa that are best adapted to the various climates and organic farming systems of Washington, Oregon, and Utah. Traits of importance will be quickly understood by growers and researchers and varieties with specific traits will be shared among other farmers at field days and conferences, and through handouts and newsletter publications. Quinoa production for seed and local consumption will begin to approach and take advantage of the demand for locally grown grains. This expanded market will encourage farmers to grow grains as a component in their current cropping rotations, resulting in increased diversity and resiliency in their farming systems. This is already being realized with wheat on small- to mid-scale farms in western Washington after a very short time span of coordinated farmer/researcher collaboration.

APPROACH

Objective 1. Identify and quantify domestic demand and future marketing opportunities for domestically grown organic quinoa. This socioeconomic research will involve surveys of quinoa distributors, wholesalers, and retailers across the US in Years 1 and 4 of the project. Dr. Goldberger, an agricultural sociologist at Washington State University (WSU), will oversee survey development, implementation, and analysis. This objective is of utmost importance as this information is not available and this is one of the most pressing questions we receive from US farmers interested in growing quinoa. Objective 2. Evaluate and select quinoa varieties and breeding lines in organic systems for critical traits of interest. Three multi-year and multi-state experiments will be conducted to help achieve the overall goals of Objective 2: 1) multi-state organic variety trials; 2) breeding line evaluation and phenotyping; and 3) salinity tolerance trials. Objective 3. Develop best management practices for organic quinoa production. Within Objective 3, two experiments will be conducted, described below. Experiment 3.1: Deficit Irrigation x Intercropping Trial Dr. Murphy and Dr. Desta will coordinate the deficit irrigation x intercropping trial. To date, the focus of the WSU quinoa program has been on dryland agriculture. In order to optimize yields in most environments, supplemental irrigation will be critical. One goal of this experiment will be to identify the most effective irrigation amounts at important stages in the quinoa life cycle. The second goal of this experiment will be to gather baseline data on the potential of leguminous intercropping on soil fertility, soil quality, and weed suppression in organic systems. Experiment 3.2: Seeding Rate, Row Spacing, and Planting Date Trial Drs. Petrie and Machado of OSU will coordinate the seeding rate and date trial in high and low rainfall regions of Oregon. The goal of this trial is to elucidate the important question of how much seed per acre should be planted to maximize production in low rainfall/dryland conditions and higher rainfall/irrigated conditions. Some of this information can be found in the literature, but it has not been identified for the target regions. Additionally, the optimal seeding dates for each mega-environment should be identified to allow for maximum days to maturity and grain yield. Objective 4. Evaluate the end-use quality traits and nutritional value of quinoa varieties and breeding lines. Dr. Baik of WSU will coordinate this component of the project. Quinoa varieties and advanced generation breeding lines will be tested for comprehensive physical and compositional characteristics of seed affecting processing and food product quality as well as nutritional value to determine the variations of traits and identify the elite lines and varieties for food uses. The early generation breeding lines will be determined for physical grain characteristics, and protein and ash contents for their screening. Progress 09/01/12 to 08/31/16 Outputs Target Audience: Farmers, consumers, quinoa researchers, processors, distributors Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Over 25 class lectures were delivered to undergraduate students since 2012 across three universities that focused on quinoa research. Three graduate students fully or partially funded through this OREI program have received their M.S. degrees, and an additional four students (2 Ph.D. and 2 M.S.) are expected to graduate by the end of this grant cycle. How have the results been disseminated to communities of interest? Selected conference presentations: Hinojosa, L., K. Gill, N. Kumar, K. Murphy (2016). High-throughput phenotyping to evaluate heat stress response

in quinoa. ASA-CSSA-SSSA International Annual Meeting, Phoenix, AZ, November 7, 2016. Murphy, K. (2016). Development of the WSU quinoa breeding program from the ground up: Lessons learned and the way forward. National Association of Plant Breeding, Webinar, April 20, 2016. Murphy, K. (2016). Breeding for nutritional and rotational diversity in dryland cereal and seed crops in the Palouse prairie ecosystem of the Pacific Northwest. Texas A&M Plant Breeding Symposium, College Station, TX, February 18, 2016. Murphy, K. (2016). Breeding grains for regional organic adaptation. Organic Seed Growers Conference, Corvallis, OR, February 5, 2016. Murphy, K., J. Kellogg, L. Hinojosa, C. Habiyaremye, M. Hagler, J. Davison (2016). Faculty-led study abroad: Agroecology and participatory research in Ecuador. Crop and Soil Science Seminar Series, Fall 2016. Pullman, WA, October 3, 2016. Murphy, K. (2016). Quinoa cultivation in western North America: Lessons learned and the path forward. ASA-CSSA-SSSA International Annual Meeting, Phoenix, AZ, November 8, 2016. Field Days and Workshops: Our research team has organized and/or participated in approximately 25 field days and workshops since 2012 that focused on quinoa production and research in Oregon, Utah, Idaho and Washington, at which an estimated 800 stakeholders participated. Graduate and undergraduate students: Over 26 class lectures were delivered to undergraduate students since 2012 across three universities that focused on quinoa research. Three graduate students fully or partially funded through this OREI program have received their M.S. degrees, and an additional four students (2 Ph.D. and 2 M.S.) are expected to graduate by the end of this grant cycle. Conference Organized and Hosted: International Quinoa Research Symposium, August 12-14, 2013. Pullman, WA. 160 participants representing 24 countries and 18 states attended the 3-day conference. A total of 14 webinars of the invited presentations were made available to the public through eXtension and YouTube. These 14 webinars have together been viewed over 7,000. What do you plan to do during the next reporting period to accomplish the goals? Our research has clearly demonstrated the need for future work. Among the highest priorities include: 1) breeding for heat tolerant varieties; 2) investigating proper management of three major pests, including stem borer, aphid and lygus bug; 3) conducting variety and agronomic trials across potential quinoa producing regions of the U.S.; 4) selection for downy mildew resistance and pre-harvest sprouting tolerance in wetter climates; 5) more focused research on agronomic questions like optimal seeding rate, planting date, fertility rates, planting and harvesting equipment, and irrigation, 6) an in-depth economic analysis to determine the profitability of regionally and domestically grown quinoa within different marketing options; and 7) continued characterization of end-use quality parameters and nutritional traits in different quinoa populations. These and other priorities can be accomplished through an expansion of our current organic research team to: 1) include scientists and farmers from across the U.S.; and 2) expand our research focus to include a strong entomology, pathology, soil fertility and microbiology component. Impacts What was accomplished under these goals? Our research has contributed to organic, domestic production by providing growers with accurate data on yield, disease resistance, heat tolerance and seed quality through multi-year evaluations of hundreds of quinoa varieties and breeding lines across diverse environments. Approximately 70% of the quinoa imported into the U.S. each year is certified organic, indicating a potential preference for organic quinoa among consumers. Based on a 2014 survey of national food co-ops, locally and/or domestically grown quinoa is also strongly preferred by U.S. consumers. In addition, we tested different methods of growing quinoa, including with and without irrigation; transplanted vs. direct seeding; hand, mechanical and weeder geese cultivation; variations in row spacing and plant density; and hand and mechanical harvesting. The extension component of this project has focused on disseminating this research to interested growers across all scales of farm management and in multiple unique climatic ecosystems. Our research team has conducted and/or facilitated 20 informative webinars, over 36 presentations at scientific and farmer meetings, and 25 field days and workshops since 2012 and we hosted an International Quinoa Research Symposium in 2013 in order to exchange ideas and share knowledge with organic stakeholders. Publications Type: Journal Articles Status: Accepted Year Published: 2016 Citation: Kowalski, R.J., I.G. Medina-Meza, B.B. Thapa, K. Murphy, G.M. Ganjyal (2016). Extrusion processing characteristics of quinoa (*Chenopodium quinoa* Willd.) var. Cherry Vanilla. *Journal of Cereal Science* 70: 91-98. Type: Journal Articles Status: Accepted Year Published: 2016 Citation: Wu, G., A.J. Peterson, C.F. Morris, K. Murphy (2016). Quinoa seed quality response to sodium chloride and sodium sulfate salinity. *Frontiers in Plant Science* 7: 790. Type: Journal Articles Status: Accepted Year Published: 2016 Citation: Walters, H., L. Carpenter-Boggs, K. Desta, L. Yan, G.J. Matanguihan, K. Murphy (2016). Effect of irrigation, intercrop and cultivar on agronomic and nutritional characteristics of quinoa. *Agroecology and Sustainable Food Systems* 40: 783-803. Type: Journal Articles Status: Accepted Year Published: 2016 Citation: Aluwi, N., B.-J. Gu, G. Dhumal, I.G. Medina-Meza, K. Murphy, G. Ganjyal (2016). Impacts of scarification and degermination on the expansion characteristics of select quinoa varieties during extrusion processing. *Journal of Food Science* 81: E2939-E2949. Type: Journal Articles Status: Accepted Year Published: 2016 Citation: Murphy, K., D. Bazile, J. Kellogg, M. Rahmanian (2016). Development of a worldwide consortium on evolutionary participatory breeding in quinoa. *Frontiers in Plant Science* 7: 608. IF=4.495. Type: Journal Articles Status: Accepted Year Published: 2017 Citation: Wu, G., C.F. Morris, K. Murphy, C.F. Ross (2017). Lexicon development, consumer acceptance, and drivers of liking of quinoa varieties. *Journal of Food Science* 82: 993-1005. Type: Journal Articles Status: Accepted Year Published: 2017 Citation: Wu, G., C. Morris, K. Murphy (2017). Quinoa starch characteristics and their correlations with the texture profile analysis

(TPA) of cooked quinoa. *Journal of Food Science* 82: 2387-2395. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Hinojosa, L., K. Gill, N. Kumar, K. Murphy (2016). High-throughput phenotyping to evaluate heat stress response in quinoa. ASA-CSSA-SSSA International Annual Meeting, Phoenix, AZ, November 7, 2016. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Murphy, K. (2016). Development of the WSU quinoa breeding program from the ground up: Lessons learned and the way forward. National Association of Plant Breeding, Webinar, April 20, 2016. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Murphy, K. (2016). Breeding for nutritional and rotational diversity in dryland cereal and seed crops in the Palouse prairie ecosystem of the Pacific Northwest. Texas A&M Plant Breeding Symposium, College Station, TX, February 18, 2016. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Murphy, K. (2016). Breeding grains for regional organic adaptation. Organic Seed Growers Conference, Corvallis, OR, February 5, 2016. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Murphy, K., J. Kellogg, L. Hinojosa, C. Habiyaremye, M. Hagler, J. Davison (2016). Faculty-led study abroad: Agroecology and participatory research in Ecuador. Crop and Soil Science Seminar Series, Fall 2016. Pullman, WA, October 3, 2016. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Murphy, K. (2016). Quinoa cultivation in western North America: Lessons learned and the path forward. ASA-CSSA-SSSA International Annual Meeting, Phoenix, AZ, November 8, 2016. Progress 09/01/15 to 08/31/16 Outputs Target Audience: Farmers, consumers, quinoa researchers, processors, distributors. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Over 25 class lectures were delivered to undergraduate students since 2012 across three universities that focused on quinoa research. Three graduate students fully or partially funded through this OREI program have received their M.S. degrees, and an additional four students (2 Ph.D. and 2 M.S.) are expected to graduate by the end of this grant cycle. How have the results been disseminated to communities of interest? Selected conference presentations: Hinojosa, L., K. Gill, N. Kumar, K. Murphy (2016). High-throughput phenotyping to evaluate heat stress response in quinoa. ASA-CSSA-SSSA International Annual Meeting, Phoenix, AZ, November 7, 2016. Murphy, K. (2016). Development of the WSU quinoa breeding program from the ground up: Lessons learned and the way forward. National Association of Plant Breeding, Webinar, April 20, 2016. Murphy, K. (2016). Breeding for nutritional and rotational diversity in dryland cereal and seed crops in the Palouse prairie ecosystem of the Pacific Northwest. Texas A&M Plant Breeding Symposium, College Station, TX, February 18, 2016. Murphy, K. (2016). Breeding grains for regional organic adaptation. Organic Seed Growers Conference, Corvallis, OR, February 5, 2016. Murphy, K., J. Kellogg, L. Hinojosa, C. Habiyaremye, M. Hagler, J. Davison (2016). Faculty-led study abroad: Agroecology and participatory research in Ecuador. Crop and Soil Science Seminar Series, Fall 2016. Pullman, WA, October 3, 2016. Murphy, K. (2016). Quinoa cultivation in western North America: Lessons learned and the path forward. ASA-CSSA-SSSA International Annual Meeting, Phoenix, AZ, November 8, 2016. Field Days and Workshops: Our research team has organized and/or participated in approximately 25 field days and workshops since 2012 that focused on quinoa production and research in Oregon, Utah, Idaho and Washington, at which an estimated 800 stakeholders participated. Graduate and undergraduate students: Over 26 class lectures were delivered to undergraduate students since 2012 across three universities that focused on quinoa research. Three graduate students fully or partially funded through this OREI program have received their M.S. degrees, and an additional four students (2 Ph.D. and 2 M.S.) are expected to graduate by the end of this grant cycle. Conference Organized and Hosted: International Quinoa Research Symposium, August 12-14, 2013. Pullman, WA. 160 participants representing 24 countries and 18 states attended the 3-day conference. A total of 14 webinars of the invited presentations were made available to the public through eXtension and YouTube. These 14 webinars have together been viewed over 7,000. What do you plan to do during the next reporting period to accomplish the goals? Our research has clearly demonstrated the need for future work. Among the highest priorities include: 1) breeding for heat tolerant varieties; 2) investigating proper management of three major pests, including stem borer, aphid and lygus bug; 3) conducting variety and agronomic trials across potential quinoa producing regions of the U.S.; 4) selection for downy mildew resistance and pre-harvest sprouting tolerance in wetter climates; 5) more focused research on agronomic questions like optimal seeding rate, planting date, fertility rates, planting and harvesting equipment, and irrigation, 6) an in-depth economic analysis to determine the profitability of regionally and domestically grown quinoa within different marketing options; and 7) continued characterization of end-use quality parameters and nutritional traits in different quinoa populations. These and other priorities can be accomplished through an expansion of our current organic research team to: 1) include scientists and farmers from across the U.S.; and 2) expand our research focus to include a strong entomology, pathology, soil fertility and microbiology component. Impacts What was accomplished under these goals? Our research has contributed to organic, domestic production by providing growers with accurate data on yield, disease resistance, heat tolerance and seed quality through multi-year evaluations of hundreds of quinoa varieties and breeding lines across diverse environments. Approximately 70% of the quinoa imported into the U.S. each year is certified organic, indicating a potential preference for organic quinoa among consumers. Based on a 2014 survey of national food co-ops, locally and/or domestically grown quinoa is also strongly preferred by U.S. consumers. In

addition, we tested different methods of growing quinoa, including with and without irrigation; transplanted vs. direct seeding; hand, mechanical and weeder geese cultivation; variations in row spacing and plant density; and hand and mechanical harvesting. The extension component of this project has focused on disseminating this research to interested growers across all scales of farm management and in multiple unique climatic ecosystems. Our research team has conducted and/or facilitated 20 informative webinars, over 36 presentations at scientific and farmer meetings, and 25 field days and workshops since 2012 and we hosted an International Quinoa Research Symposium in 2013 in order to exchange ideas and share knowledge with organic stakeholders.

Publications Type: Journal Articles Status: Published Year Published: 2016 Citation: Aluwi, N., B-J. Gu, G. Dhupal, I.G. Medina-Meza, K. Murphy, G. Ganjyal (2016). Impacts of scarification and degermination on the expansion characteristics of select quinoa varieties during extrusion processing. *Journal of Food Science* 81: E2939-E2949. Type: Journal Articles Status: Published Year Published: 2016 Citation: Walters, H., L. Carpenter-Boggs, K. Desta, L. Yan, G.J. Matanguihan, K. Murphy (2016). Effect of irrigation, intercrop and cultivar on agronomic and nutritional characteristics of quinoa. *Agroecology and Sustainable Food Systems* 40: 783-803. Type: Journal Articles Status: Published Year Published: 2016 Citation: Murphy, K., D. Bazile, J. Kellogg, M. Rahmanian (2016). Development of a worldwide consortium on evolutionary participatory breeding in quinoa. *Frontiers in Plant Science* 7: 608. Type: Journal Articles Status: Published Year Published: 2016 Citation: Wu, G., A.J. Peterson, C.F. Morris, K. Murphy* (2016). Quinoa seed quality response to sodium chloride and sodium sulfate salinity. *Frontiers in Plant Science* 7: 790. Type: Journal Articles Status: Published Year Published: 2016 Citation: Maliro, M.F.A., V.F. Guwela, J. Nyaika, K. Murphy (2017). Preliminary studies of the performance of quinoa (*Chenopodium quinoa* Willd.) genotypes under irrigated and rainfed conditions of central Malawi. *Frontiers in Plant Science* 8:227. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Murphy, K. (2016). Quinoa cultivation in western North America: Lessons learned and the path forward. ASA-CSSA-SSSA International Annual Meeting, Phoenix, AZ, November 8, 2016. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Murphy, K., J. Kellogg, L. Hinojosa, C. Habiyaemye, M. Hagler, J. Davison (2016). Faculty-led study abroad: Agroecology and participatory research in Ecuador. *Crop and Soil Science Seminar Series, Fall 2016*. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Murphy, K. (2016). Breeding for nutritional and rotational diversity in dryland cereal and seed crops in the Palouse prairie ecosystem of the Pacific Northwest. *Texas A&M Plant Breeding Symposium, College Station, TX, February 18, 2016*. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Hinojosa, L., K. Gill, N. Kumar, K. Murphy (2016). High-throughput phenotyping to evaluate heat stress response in quinoa. ASA-CSSA-SSSA International Annual Meeting, Phoenix, AZ, November 7, 2016.

PROGRESS

2014/09 TO 2015/08 Target Audience: The primary stakeholders of this project include organic growers, and current quinoa distributors, wholesalers, and retailers. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Graduate and undergraduate students: Over 22 class lectures were delivered to undergraduate students since 2012 across three universities that focused on quinoa research. Three graduate students fully or partially funded through this OREI program have received their M.S. degrees, and an additional four students (2 Ph.D. and 2 M.S.) are expected to graduate by the end of this grant cycle on June 30, 2016. How have the results been disseminated to communities of interest? Extension and/or education activities completed or upcoming: Conference Organized and Hosted: International Quinoa Research Symposium, August 12-14, 2013. Pullman, WA. 160 participants representing 24 countries and 18 states attended the 3-day conference. A total of 14 webinars of the invited presentations were made available to the public through eXtension and YouTube. These 14 webinars have together been viewed 6,753 times as of Oct. 6, 2015. Webinars: Keen on quinoa breeding. National Institute of Plant Breeding Webinar Series titled 'How to breed new plant varieties: Imagining and engineering crops', June 3, 2014. 346 views as of Oct. 6, 2015. Quinoa breeding for North America. TCAP Webinar Series: 'Ahead of the curve: Technologies for next generation plant breeding' March 20, 2013. 45 views as of Oct. 6, 2015. Organic quinoa production in the Pacific Northwest. eOrganic Webinar Series, February 25, 2013. 17,825 views as of Oct. 6, 2015. *Webinar scheduled with eOrganic for March 2016 that will serve as an update of our research since the 2013 eOrganic webinar. Selected invited conference presentations: Our research team has given over 18 oral presentations and 16 poster presentations at scientific conferences and grower meetings from 2012 to present. A representative sample is presented here. Development of a worldwide consortium on evolutionary participatory breeding in quinoa. European Association of Plant Breeding: International Symposium on Protein Crops V. Pontevedra, Spain, May 5, 2015. Challenges and opportunities of breeding quinoa in the Pacific Northwest. University of Minnesota Plant Breeding Symposium, Minneapolis, MN, March 27, 2015. Growing and marketing specialty grain crops in the Pacific Northwest. Cascadia Grains Conference, Olympia, WA, Jan. 10, 2015. Cultivating the future: Growing the Northwest quinoa crop. Washington State University Innovators Luncheon, Seattle, WA, April 24,

2014. Growing quinoa in the Pacific Northwest. Oregon Small Farms Conference, Corvallis, OR, Feb. 22, 2014. Specialty grain production in the Pacific Northwest: Examples from amaranth, buckwheat, millet, spelt and quinoa. Cascadia Grains Conference, Tacoma, WA, Jan. 11, 2014. Organic quinoa production. Washington Tilth Producers Annual Conference, Yakima, WA, Nov. 10, 2013. Breeding for farmers needs: Quinoa, barley and buckwheat. Student Organic Seed Symposium, Mount Vernon, WA, Aug. 5, 2013. Quinoa production in the Pacific Northwest. Focus on Farming Conference. Everett, WA, Nov. 15, 2012. Field Days and Workshops: Our research team has organized and/or participated in approximately 20 field days and workshops since 2012 that focused on quinoa production and research in Oregon, Utah, Idaho and Washington, at which an estimated 800 stakeholders participated. What do you plan to do during the next reporting period to accomplish the goals? Our research has clearly demonstrated the need for future work. Among the highest priorities include: 1) breeding for heat tolerant varieties; 2) investigating proper management of three major pests, including stem borer, aphid and lygus bug; 3) conducting variety and agronomic trials across potential quinoa producing regions of the U.S.; 4) selection for downy mildew resistance and pre-harvest sprouting tolerance in wetter climates; 5) more focused research on agronomic questions like optimal seeding rate, planting date, fertility rates, planting and harvesting equipment, and irrigation, 6) an in-depth economic analysis to determine the profitability of regionally and domestically grown quinoa within different marketing options; and 7) continued characterization of end-use quality parameters and nutritional traits in different quinoa populations. These and other priorities can be accomplished through an expansion of our current organic research team to: 1) include scientists and farmers from across the U.S.; and 2) expand our research focus to include a strong entomology, pathology, soil fertility and microbiology component.

2013/09 TO 2014/08 Target Audience: Target audiences reached by our efforts include: farmers, processors, distributors, scientists, students, and end users. We reached these target audiences through a multi-pronged approach. This included field days across the region target primarily to farmers; undergraduate student internships; formal classroom instruction in four distinct courses; a International Quinoa Research Symposium; webinars and multiple invited and/or keynote presentations at local, regional, national and international levels. Changes/Problems: Nothing Reported What opportunities for training and professional development has the project provided? Nothing Reported How have the results been disseminated to communities of interest? Results have been disseminated to communities through multiple field days in Washington, Oregon and Utah. Several poster presentations showcasing quinoa research were held at venues including the 2014 WSU BIOAg Symposium 'Saving Nature and Improving Agriculture: Where does Nature's Wisdom Lie?'; the American Association of Cereal Chemistry Annual Meeting in 2014 in Providence, Rhode Island; the Experimental Biology Annual Meeting in San Diego, California in 2014; the WSU Academic Showcase in Pullman, WA; Tilth Producers Annual Conference in Yakima, WA in 2013. Invited oral presentations were delivered at the Cascadia Grains Conference in Olympia in 2014 and 2015; for the Greater Spokane Incorporated Agribusiness Council; at the SOLIBAM Congress in 2014 in Nantes, France; at the Berkeley Food Institute, UC Berkeley; at the WSU Innovators Luncheon in Seattle, WA; at the Oregon Small Farms Conference in Corvallis, OR, and at the Washington Tilth Producers Annual Conference in Yakima, WA. What do you plan to do during the next reporting period to accomplish the goals? 1. Continue multi-state organic variety trials. 2. Continue salinity trials. 3. Continue heat tolerance trials in the field, lab and greenhouse. 4. Publish results on the intercropping trials. 5. Publish results on Food Co-op survey. 6. Submit a survey to WA State organic farmers about quinoa production. 7. Continue agronomic trials on seeding rate and date.

2012/09 TO 2013/08 Target Audience: A wide range of people representing various segments of our target audience were reached through efforts that included: 1) classroom teaching to university undergraduates; 2) five multi-state research and extension field days; 3) a national organic student seed symposium presentation and field day for graduate students; 4) a webinar on organic quinoa production (<http://www.youtube.com/watch?v=V7jVdwrFSA>) through eOrganic and YouTube (1,644 views from February 26, 2013 to August 30, 2013); 5) poster presentations at regional, national and international meetings; and 6) an International Quinoa Research Symposium (<https://www.etches.com/ehome/quinoa/>) hosted by Washington State University, which had 150 in-person attendees (representing 23 countries) and an average of 50 online attendees per presentation. The symposium was recorded by eOrganic and available at the following website: <http://www.extension.org/pages/68467/international-quinoa-research-symposium-br>

IMPACT

2014/09 TO 2015/08 What was accomplished under these goals? Approximately 70% of the quinoa imported into the U.S. each year is certified organic, indicating a potential preference for organic quinoa among consumers. Based on a 2014 survey of national food co-ops, locally and/or domestically grown quinoa is also strongly preferred by U.S. consumers. Our research has contributed to organic, domestic production by providing growers with accurate data on yield, disease resistance, heat tolerance and seed quality through multi-year evaluations of hundreds of quinoa varieties and breeding lines across diverse environments. In addition, we tested different methods of growing quinoa, including with and without irrigation; transplanted vs. direct seeding; hand, mechanical and weeder geese cultivation; variations in row spacing and plant density; and hand and mechanical harvesting. The extension component of this project has focused on disseminating this research to interested growers across all scales of farm management and in multiple unique climatic ecosystems. Our research team has conducted and/or facilitated 17 informative webinars, over 30 presentations at scientific and farmer meetings, and 20 field days and workshops since 2012 and we hosted an International Quinoa Research Symposium in 2013 in order to exchange ideas and share knowledge with organic stakeholders. **PUBLICATIONS (not previously reported):** 2014/09 TO 2015/08 1. Type: Journal Articles Status: Published Year Published: 2015 Citation: Peterson, A.J., S.-E. Jacobsen, A. Bonifacio, K. Murphy¹* (2015). A crossing method for quinoa (*Chenopodium quinoa*). *Sustainability* 7: 3230-3243. 2. Type: Book Chapters Status: Published Year Published: 2015 Citation: Matanguihan, J.B., P.J. Maughan, E.N. Jellen, B. Kolano (2015). Quinoa Cytogenetics, Molecular Genetics and Diversity, In: *Quinoa: Improvement and Sustainable Production*, K.M. Murphy and J.G. Matanguihan, (eds.), Wiley-Blackwell. Hoboken, New Jersey, USA. 3. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Development of a worldwide consortium on evolutionary participatory breeding in quinoa. European Association of Plant Breeding: International Symposium on Protein Crops V. Pontevedra, Spain, May 5, 2015. 4. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Challenges and opportunities of breeding quinoa in the Pacific Northwest. University of Minnesota Plant Breeding Symposium, Minneapolis, MN, March 27, 2015. 5. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Growing and marketing specialty grain crops in the Pacific Northwest. Cascadia Grains Conference, Olympia, WA, Jan. 10, 2015. 6. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Khati, K., J. Davenport, K.G. Desta, K. Murphy (2015). Effect of Organic Nitrogen Amendments and Irrigation Regimes on Agronomic Performance of Two Quinoa (*Chenopodium quinoa* Willd.) Cultivars. ASA-CSSA-SSSA International Annual Conference, Minneapolis, MN, November 15-18, 2015. 7. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Hinojosa, L., K. Murphy, G. Wu (2015). Quinoa photoperiod sensitivity. ASA-CSSA-SSSA International Annual Conference, Minneapolis, MN, November 15-18, 2015. 8. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Nichols, V.A., K. Murphy, K. Schroeder (2015). Direct-seeded quinoa: Some considerations. ASA-CSSA-SSSA International Annual Conference, Minneapolis, MN, November 15-18, 2015. 9. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Buckland, K., J. Reeve, E. Creech (2015). Developing organic quinoa cropping systems for quinoa. ASA-CSSA-SSSA International Annual Conference, Minneapolis, MN, November 15-18, 2015. 10. Type: Book Chapters Status: Published Year Published: 2015 Citation: Peterson, A.J., K. Murphy (2015). Quinoa Cultivation for Temperate North America: Considerations and Areas for Investigation, In: *Quinoa: Improvement and Sustainable Production*, K.M. Murphy and J.G. Matanguihan, (eds.), Wiley-Blackwell. Hoboken, New Jersey, USA. 11. Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Reeve, J., K. Buckland, A. Nafziger (2015). Developing quinoa for production in Utah. Western Society of Crop Science, June 16-17, Logan, UT.

2013/09 TO 2014/08 What was accomplished under these goals? 1. Identify and quantify demand and future marketing opportunities for domestically grown organic quinoa. A PhD student, Emily Green-Tracewicz, in collaboration with Dr. Jessica Goldberger has developed and sent out a survey to Food Cooperatives across the US. The data has been compiled and is currently being analyzed. Research results have been presented at two conferences to date. 2. Evaluate and select quinoa varieties and breeding lines in organic systems for critical traits of interest. In 2014, 7 variety trials consisting of 30 varieties and 6 breeding lines were grown on farms in three states, including Washington (3 sites), Oregon (3 sites), and Utah (1 site). Morphological characteristics were evaluated throughout the growing season, as well as disease and insect resistance. Yield and other post-harvest traits were recorded in Fall 2014. Additionally, 10 advanced early generation populations were grown on organic farms in Pullman and Quilcene, WA. 3. Develop best management practices for organic quinoa production. Intercropping trials were completed in Utah and Washington (2 separate trials), and are currently being written up for publication. Heat tolerance trials are in progress in Lewiston, Idaho and Prosser, Washington. A pilot salinity trial was planted in Utah, and a greenhouse salinity trial at WSU was completed and a manuscript was accepted and published in *Crop Science* in 2015. A seeding rate/planting date/row spacing trial was planted at two locations in Oregon. 4. Evaluate the end-use quality traits and nutritional value of quinoa varieties and breeding lines. Quinoa varieties from the greenhouse salinity x nitrogen trial were analyzed for a suite of end-use

quality and nutritional traits. This manuscript is currently in progress. Additionally, 14 other quinoa varieties from the field were analyzed for end-use quality traits and nutritional value and results from this paper were published in *Journal of Food Science* in 2014.

5. Disseminate information about, and develop farmer/distributor relationships for, organic quinoa production and marketing. Several field days were held across three states during Summer 2014 that provided connections for farmers and marketers of quinoa. A webinar was conducted in 2013 that discussed organic quinoa production and marketing. **PUBLICATIONS (not previously reported):**

2013/09 TO 2014/08

1. Type: Journal Articles Status: Published Year Published: 2015 Citation: Peterson, A. and K. Murphy (2015). Tolerance of lowland quinoa cultivars to sodium chloride and sodium sulfate salinity. *Crop Science* 55: 331-338.
2. Type: Journal Articles Status: Published Year Published: 2014 Citation: Wu, G., K. Murphy, C. Morris (2014). Evaluation of texture differences among varieties of cooked quinoa. *Journal of Food Science* 79(11): S2337-S2345.
3. Type: Journal Articles Status: Under Review Year Published: 2015 Citation: Peterson, A.J., K. Murphy, S.-E. Jacobsen, A. Bonifacio (in review). A crossing method for quinoa (*Chenopodium quinoa*). Submitted to *Sustainability*.
4. Type: Books Status: Awaiting Publication Year Published: 2015 Citation: Murphy, K., J.B. Matanguihan (eds.) (2015, in press). *Quinoa: Improvement and Sustainable Production*, Wiley-Blackwell. Hoboken, New Jersey, USA.
5. Type: Book Chapters Status: Awaiting Publication Year Published: 2015 Citation: Peterson, A.J., K. Murphy (2015). Quinoa Cultivation for Temperate North America: Considerations and Areas for Investigation, In: *Quinoa: Improvement and Sustainable Production*, K.M. Murphy and J.G. Matanguihan, (eds.), Wiley-Blackwell. Hoboken, New Jersey, USA.
6. Type: Journal Articles Status: Published Year Published: 2014 Citation: Peterson, A.J., K. Murphy (2014). Quinoa in the USA and Canada, In: *The State of the World's Quinoa*, D. Bazile (ed.), Food and Agriculture Organization, Rome, Italy.
7. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Noratto, G., R. Carrion-Rabanal, K. Murphy, G. Ganjyal, R. Kowalski (2014). Quinoa as a source of bioactive compounds with potential for intestinal health. *Experimental Biology Annual Meeting 2014*, San Diego, April 2014. Abstract published in *FASEB JOURNAL* APR 2014, 28:647.18.
8. Type: Other Status: Published Year Published: 2014 Citation: Murphy, K. (2014). Keen on quinoa breeding. *National Institute of Plant Breeding Webinar Series* titled "How to breed new plant varieties: Imagining and engineering crops?", June 3, 2014.
9. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Murphy, K., M. Dillon, C. Brummer, L. Carlisle (2014). Developing seeds in diversified farming systems: A panel discussion. *Berkeley Food Institute, University of California, Berkeley*, April 28, 2014.
10. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Murphy, K., (2014). Cultivating the future: Growing the Northwest quinoa crop. *Washington State University Innovators Luncheon*, Seattle, WA, April 24, 2014.
11. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Murphy, K. and F. Morton (2014). Growing quinoa in the Pacific Northwest. *Oregon Small Farms Conference*, Corvallis, OR, February 22, 2014.
12. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Murphy, K. (2014). Specialty grain production in the Pacific Northwest: Examples from amaranth, buckwheat, millet, spelt and quinoa. *Cascadia Grains Conference*, Tacoma, WA, January 11, 2014.
13. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Murphy, K. and I. Clark (2013). Organic quinoa production. *Washington State Tilth Producers Annual Conference*, Yakima, WA, November 10, 2013.
14. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Wu, G., C.F. Morris, K. Murphy (2014). Quinoa starch characteristics and their correlations to cooking quality. *WSU BIOAg Symposium, Saving Nature and Improving Agriculture: Where does Nature's Wisdom Lie?* Pullman, WA, October 28, 2014.
15. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Wu, G., C.F. Morris, K. Murphy (2014). Evaluation of texture differences among varieties of cooked quinoa. *American Association of Cereal Chemistry Annual Meeting*, Providence, Rhode Island, October 6, 2014.
16. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Noratto, G., R. Carrion-Rabanal, K. Murphy, G. Ganjyal, R. Kowalski (2014). Quinoa as a source of bioactive compounds with potential for intestinal health. *Experimental Biology Annual Meeting 2014*, San Diego, April 2014.
17. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Peterson, A. and K. Murphy (2013). Pre-harvest sprouting, mold susceptibility, senescence, and seed set in quinoa cultivars grown in Northwest Washington State. *Tilth Producers Conference*, Yakima, WA, Nov. 11, 2013.
18. Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Wu, G., C.F. Morris, and K. Murphy (2014). Texture differences of cooked quinoa among thirteen varieties. *WSU Academic Showcase*, Pullman, WA, March 29, 2014.
19. Type: Theses/Dissertations Status: Published Year Published: 2014 Citation: Hannah Walters, MS in Crop Science, Graduated Spring 2014 Thesis: *Agronomic and Nutritional Characteristics of Quinoa Grown under Different Intercrop and Irrigation Regimes in an Organic System*
20. Type: Theses/Dissertations Status: Published Year Published: 2014 Citation: Adam Peterson, MS in Crop Science, Graduated Spring 2013 Thesis: *Salinity Tolerance and Nitrogen Use Efficiency of Quinoa for Expanded Production in Temperate North America*
21. Type: Theses/Dissertations Status: Published Year Published: 2014 Citation: Morgan Gardner, MS in Environmental Science, Graduated Summer 2013 Thesis: *Assessing the Potential Adoption of Quinoa for Consumption in Central Malawi*
22. Type: Theses/Dissertations Status: Published Year Published: 2015 Citation:

MS Thesis, Rocio Jackelyn Carrion Rabanal Assessing the Andean Crops Sacha Inchi and Quinoa for their bioactive compounds and their potential health benefits

2012/09 TO 2013/08 What was accomplished under these goals? Accomplishments in relation to the research and extension objectives stated above. 1. Identify and quantify demand and future marketing opportunities for domestically grown organic quinoa. A PhD student was identified and funded who will be working on the first stage of this objective. To date, potential markets to survey have been identified, and a list of questions has been drafted. The survey will be sent to retail markets in Year 2 of the project. 2. Evaluate and select quinoa varieties and breeding lines in organic systems for critical traits of interest. First-year variety trials, consisting of 26 varieties and 6 breeding lines are being grown on organic farms in four states, including Washington (2 sites), Oregon (1 site), Utah (1 site) and Idaho (1 site). At the time of this progress report, all plots are still standing in the field, approximately two to three weeks from harvest. Morphological characteristics have been evaluated throughout the growing season, as well as disease and insect resistance. Yield and other post-harvest traits will be recorded in Fall 2013 and available through the project website. Additionally, 800+ advanced breeding lines are currently growing as headrows at WSU in Pullman. These are being phenotyped and will complement genotype data generated by BYU. The most promising of these lines will be included in the organic variety trials in 2014. 3. Develop best management practices for organic quinoa production. Intercropping trials are currently underway in Utah and Washington (2 separate trials). Heat tolerance trials are in progress in Lewiston, Idaho and Prosser, Washington. A pilot salinity trial was planted in Utah, and a greenhouse salinity trial at WSU was completed and a manuscript is currently in preparation. A seeding rate/planting date/row spacing trial was planted at two locations in Oregon. All trials are currently in progress and results will be available in Fall/Winter of 2013/2014. 4. Evaluate the end-use quality traits and nutritional value of quinoa varieties and breeding lines. Quinoa varieties from the greenhouse salinity x nitrogen trial are currently being analyzed for a suite of end-use quality and nutritional traits. Additionally, 14 other quinoa varieties from the field are being analyzed for end-use quality traits and nutritional value. 5. Disseminate information about, and develop farmer/distributor relationships for, organic quinoa production and marketing. Five field days were held across three states during Summer 2013 that provided connections for farmers and marketers of quinoa. A webinar was conducted in February 2013 that discussed organic quinoa production and marketing. The International Quinoa Research Symposium hosted farmers and distributors, processors, and retailers from over 14 states in the US (a total of 23 countries were represented at the symposium), and many valuable connections were forged. **PUBLICATIONS (not previously reported):** 2012/09 TO 2013/08 1. Type: Conference Papers and Presentations Status: Other Year Published: 2012 Citation: Walters, H. and K. Murphy (2012). Breeding and agronomy of quinoa (*Chenopodium quinoa*). WSU Center for Sustaining Agriculture and Natural Resources 20th Anniversary Symposium. Dec. 6, 2012. 2. Type: Conference Papers and Presentations Status: Other Year Published: 2012 Citation: Peterson, A. and K. Murphy (2012). Salinity tolerance of four lowland varieties of quinoa (*Chenopodium quinoa* Willd.): responses to three levels of NaCl and Na₂SO₄ under two fertilization levels. CSSA-ASA-SSSA Annual Meeting, Cincinnati, OH, October 2012. 3. Type: Conference Papers and Presentations Status: Other Year Published: 2013 Citation: Murphy, K. (2013). Opening remarks: Quinoa research at Washington State University. International Quinoa Research Symposium, August 12, 2013. 4. Type: Other Status: Other Year Published: 2012 Citation: Murphy, K. (2012). Quinoa production in the Pacific Northwest. Focus on Farming Conference. Everett, WA, November 15, 2012.

[↑ Return to Index](#)

Forage-based Parasite Control in Sheep and Goats in the Northeast U.s.

Accession No.	0230779
Subfile	CRIS
Project No.	WVA00900
Agency	NIFA WVA
Project Type	OTHER GRANTS
Project Status	NEW
Contract / Grant No.	2012-51300-20320
Proposal No.	2012-02290
Start Date	01 SEP 2012
Term Date	31 AUG 2016
Grant Amount	\$1,850,360
Grant Year	2012
Investigator(s)	Kotcon, J.; Bowdridge, S.; Bryan, W.; Petersson, K.; Stanton, T.; Zajac, A.; Brown, R.; Reed, J. D.; Krueger, C.; Shanmuganayagam, D.
Performing Institution	Plant & Soil Sciences, WEST VIRGINIA UNIVERSITY, PO BOX 6108

NON-TECHNICAL SUMMARY

This proposal establishes a multi-state, multi-disciplinary project to enhance productivity and profitability of organic livestock production in the Northeast US. Specifically, we plan to conduct coordinated research into the single most important limiting factor in organic sheep and goat production: gastro-intestinal nematode (GIN) parasites. We will evaluate high tannin forages and assess their efficacy for suppressing GIN parasites, identify the mechanism(s) of suppression, then demonstrate these improved pasture management practices on existing farms and extend these practices to organic and transitioning growers. A variety of intestinal roundworm species infect small ruminants in the Northeast and throughout the world. *Haemonchus contortus* (*H. contortus*, AKA barber pole worm) is generally considered the most important and has a life cycle typical of many other species. Symptoms of infection are associated with blood loss, and include anemia, pale color of mucous membrane, edema or bottle-jaw, severe loss of condition and poor growth. In severe infections, death may occur within a few days of the appearance of initial symptoms. Young lambs and kids tend to be most susceptible, as adults tend to develop resistance as they mature. Monitoring programs rely on clinical symptoms or on fecal egg counts (FEC), and growers must treat with anthelmintics, resulting in loss of organic certification. Low levels of infection may result in poor growth, sometimes without any other symptoms, thus making production unprofitable. One of the most promising findings in the last fifteen years has been the discovery that consumption of some forages containing condensed tannins (CT) can suppress GIN infection. CT-containing forages, by themselves, may have the potential to provide adequate control of GIN parasites. Tannins, in low to moderate concentration, increase nitrogen utilization in ruminants and subsequently have been shown to increase growth over and above the observed anthelmintic effect. Unfortunately, few studies have fully characterized the tannin profiles of the forages used. We will screen a range of cultivars, isolate the tannins involved, and screen for biological activity in vitro and in vivo. We will bring powerful analytical capability (MALDI-TOF MS) to characterize the molecular weight distribution and structural features of CT from the most promising BFT accessions based on agronomic performance, and in vitro and in vivo anthelmintic activity. Field and lab trials at URI and WVU will assess the BFT varieties for their effect on sheep by examining, anthelmintic effects, immune responses in sheep, and overall performance of organic lamb in the field. Additional grower trials will be coordinated through Cornell University to demonstrate grower adoption of these approaches.

OBJECTIVES

This proposal establishes a multi-state, multi-disciplinary project to enhance productivity and profitability of organic livestock production in the Northeast US. Specifically, we plan to conduct coordinated research into the single most important limiting factor in organic sheep and goat production: gastro-intestinal nematode (GIN) parasites. We will evaluate high tannin forages and assess their efficacy for suppressing GIN parasites, identify the mechanism(s) of suppression, then demonstrate these improved pasture management practices on existing farms and extend these practices to organic and transitioning growers. Research Objectives: 1) Evaluate birdsfoot trefoil cultivars to assess agronomic characteristics and tannin contents, identify which condensed tannins are critical for anthelmintic activity and characterize the structure/function relationship of the tannin profiles; 2) Assess the effects of high tannin forages on the larval and adult nematode response in vitro and in vivo, and measure key immune responses of the host animal; and 3) Evaluate herd health and economic outcomes of pasture mixes with high-tannin birdsfoot trefoil for suppression of intestinal parasites. Outreach and Extension Objectives: 4) Demonstrate the real-world potential to reduce parasite burden in small ruminants through on-farm comparisons of pastures with and without birdsfoot trefoil forages; 5) Promote grower adoption of organic parasite control practices through IPM workshops, field days, and presentations at grower organizations, and document changes in grower behavior; 6) Use traditional outreach tools such as short fact sheets, and articles in agriculture and livestock publications of interest to growers, as well as electronic media such as eXtension and eOrganic to develop Communities of Practice and provide results to growers, crop advisors, Extension agents, and others; and 7) Assist farmers to realize increased earnings by documenting four criteria among participating growers: a) reduced use of synthetic dewormers, b) increased animal productivity attributed to lower worm loads, c) reduced number of animals removed from organic marketing channels because of dewormer intervention and d) successful transition from conventional to organic farming due to increased confidence in coping with parasite issues.

APPROACH

Birdsfoot trefoil (BFT) accessions identified as having moderate to high levels of total condensed tannins (CTs) will be screened to assess tannin profiles, as well as plant survival, growth habit, flowering time, forage yield, regrowth after cutting, and any insect or disease damage. Hay will be used for profiling of condensed tannins and in vitro testing of anthelmintic activity. CTs will be isolated from select BFT accessions. Purity of each CT fraction will be determined by MALDI-TOF MS, HPLC and elemental analysis and CTs will be quantified by the DMAC method and analyzed by mass spectrometry. Anthelmintic properties of BFT varieties will be evaluated using in vitro assays of *H. contortus* egg hatch, larval development and exsheathment and in vivo assays with: a) fistulated sheep fed selected varieties of BFT hay to assess larval exsheathment in the rumen, and b) lambs fed BFT hay and experimentally infected with *H. contortus* to determine the effect of BFT hay consumption on FEC, blood packed cell volume, weight gain and abomasal worm burden. Parasite-naive lambs (i.e., not previously exposed to GIN parasites), will be infected with 10,000 L3 *H. contortus* 4 weeks after weaning for 28 days and then treated with the anthelmintic drug Levamisole and rested for 4 weeks to test immune responses to BFT. Lymphocyte proliferation assays will be performed with 0, 10, 20, 40 µg/ml CT extract. The effects of feeding BFT on immunity will also be assessed using lambs with three infection statuses; naive, primary (first exposure to *H. contortus*) and challenge (second exposure to *H. contortus*). After feeding CT-rations for 2 weeks, lambs will then be experimentally infected with 10,000 L3 *H. contortus* larvae. Serum IgG, IgA and IgE antibody responses will be quantified on a total and antigen-specific basis. Fecal samples will be collected weekly and FEC enumerated. Four commercial cultivars will be established at the WVU Organic Research Farm in 2012 to evaluate productivity and phenology, and to produce adequate forage to assess palatability to sheep and to provide material as needed for feeding studies. A second multi-year field experiment will evaluate lamb performance and response to forages and grazing management in pastures interseeded with commercially available cultivars of a low-CT BFT, a high-CT BFT, or red clover as a control. Lambs will be exposed to either low or high levels of field infection achieved through grazing management. The experiment will consist of three grazing phases: 1) nursing lambs and ewes contaminate pastures; 2) nursing lambs and ewes re-graze contaminated pastures to achieve low or high infection rates, and 3) weaned lambs re-graze pastures to evaluate growth and maintenance of organic status with low or high CT BFTs. The experiment will test whether lambs exposed to a high level of infestation can be "rescued" by grazing high tannin forage pastures with an evasive management strategy and whether there is residual anthelmintic activity in lambs on BFT pastures. Progress 09/01/12 to 08/31/17 Outputs Target Audience: The Target Audiences were sheep and goat producers in the Northeast US. Specifically, we expanded field testing birdsfoot trefoil pastures with eight producers in 2016 to manage parasites in sheep or goats. Five parasite workshops and seven grower presentations were held from Oct. 2016 to November 2017, including

one focused on veterinarians, with 15 veterinarian participants. Over 200 people participated in the workshops, and 167 people received FAMACHA training and certification. Seven field days and pasture walks focusing on organic management of sheep and goats and forage management to reduce parasite infection in sheep and goats were held during 2017. Workshops on alternative forages with potential to assist in parasite management were also taught by participating researchers and farmers. Changes/Problems: Sustainability of BFT stands and how to incorporate them into a grazing plan permitting weaned lambs and kids to have access to clean BFT fields for 4 weeks or more remains a major obstacle to wider adoption by growers. Two case study farms with average stands of 65% and 54% BFT during their grazing studies had the stands greatly reduced in later years with mugwort and/or conventional pasture plants outcompeting BFT. These losses may be attributed to grazing the stands too soon before the first killing frost in the fall (within 4 weeks) or to inability to control rhizome weeds. In contrast other farms completing BFT studies in 2015 or 2016 maintained stands of 37%, 54%, 57%, 86% in 2017. One experienced farm (57% BFT) was successful although they had been fighting an established stand of Canadian Thistle throughout the study. The farmer mowed the field short frequently to organically control this rhizome weed. In one case (37% BFT), the soil pH was 5.3 and never corrected thus Bruce BFT had little competition although more and more grasses came into the field each year possibly due to the BFT improving fertility. In the other cases, farmers were fairly aggressive about mowing the fields to set back conventional pasture plants and allow BFT to grow. Initially farmers and researchers were very concerned about mowing BFT low, as recommendations suggested that mowing below 5 inches slowed regrowth. Therefore farmers sometimes tried to mow above the BFT current height and below competition, for example at 8 inches. These higher mowings appeared to barely set back the weeds and did not provide as much advantage for BFT as mowing at 5 inches appeared to do at other experienced farms. However, more structured studies are needed to clearly determine what mowing heights are best for allowing a BFT stand to compete with weeds, clovers and cool season grasses and remain sustainable. Educational fact sheets for distribution have taken longer to develop than anticipated. One reason for delay is that statistical analyses of the on-farm grazing studies has just recently been completed. It is difficult to create factsheets advising people on the effect of BFT on worm loads and how best to use it and varieties to select when still in the midst of research with no clear answers to these questions. Continued research needs to be done to answer questions such as how to maintain high levels of BFT in stands, and the optimum way to manage pastures to maximize sheep health benefits. The BFT varieties used (Bruce and Pardee) do not act as highly efficient dewormers when grazed for 4 weeks at $\geq 25\%$ of the biomass, or for longer periods if the proportion of BFT biomass in the forage is $< 25\%$. Results from the on-farm grazing studies suggest that farmers with a strong agronomy background or who hire out planting / establishment to consultants with such backgrounds can successfully establish stands of $\geq 25\%$ BFT in the Northeast. Results also indicate that weight gains on BFT are improved for weaned lambs and kids being marketed as grass-fed as compared to same animals on typical forages especially when soil conditions are less optimal (acidic, low fertility, poorly drained) so that clovers and cool season grasses cannot easily compete with BFT. Worm loads and FAMACHA scores were improved over time in some trials for animals grazing BFT versus other forages. However, whether this was due to better nutrition or anthelmintic properties is not proven by these studies. What opportunities for training and professional development has the project provided? At least six graduate students and over 20 undergraduates received training on organic sheep production, nematode parasite management, and research methods as part of this project. Over 600 participants in our Integrated Parasite Control / FAMACHA® Training workshops from 2012 through 2017 received FAMACHA certification. One of the on-farm grazing trials took place at a farm learning center where ten farm interns were trained to take fecal samples and FAMACHA score goats. The List serv, BIRDSFOOTTREFOILFARMERSTUDY-L@cornell.edu was established in April 2014 to assist communication among the on-farm study farmers, extension staff and researchers with experience managing BFT test plots and grazing trials. Some of the farmers are organic inspectors or grazing consultants. Topics for 2016 have included frost seeding and assessing drought conditions in the region and its impacts on grower plots. How have the results been disseminated to communities of interest? Papers on the anthelmintic efficacy of birdsfoot trefoil and immunological responses of sheep were presented at professional meetings, and manuscripts for publication in peer-reviewed journals are in preparation. Results have been disseminated to grower and practitioner communities of interest primarily through presentations at various winter conferences and symposiums. Now that data from the on-farm planting and grazing studies has been statistically analyzed, factsheets and articles can be prepared for publication on eXtension and eOrganic, and in farmer magazines. Farmers conducting on-farm planting and grazing trials and researchers on the project met at Cornell Univ. in 2014 and again on June 26 - 27, 2017 to share their experiences. Representatives from eight of the farms and four researchers from WVU and URI were able to attend the 2017 meeting which also included Cornell extensionists, graduate students, parasitology lab staff and veterinarians participating in the project. Two other farmers attended online while 2 farmers were unable to attend for medical reasons. During the meeting, researchers and farmers toured two of the case study farms, nine farmers (one online) gave short presentations about their experiences and the 4 researchers provided in-depth presentations overviewing their research. The researcher presentations were videotaped and edited as UTube presentations. However, because the data has

not yet been published they were not put on Utube but instead were only put on memory sticks for the four farmers unable to attend the meeting to review. Updated, preliminary results from on-farm grazing trials are available online to farmers through our project website at <http://web.uri.edu/sheepngoat/orei-resources/> What do you plan to do during the next reporting period to accomplish the goals? Nothing Reported Impacts What was accomplished under these goals? Impacts achieved by this project include development of a repeatable protocol for in vitro assays of aqueous extracts of birdsfoot trefoil (BFT) for their effects on larval exsheathment within the rumen of fistulated ewes. The reduction in nematode infection and improved weight gain of lambs on BFT pastures was also observed on several grower farms. Growers who completed the workshops reported increased confidence in their ability to manage nematodes organically, and reported a decrease in costs of dewormer averaging \$143 per grower. Objective 1) Successful organic cultivation of BFT benefits from high seeding rates (e.g., 20 lb/Acre) to compensate for the inability to use herbicides at planting. All commercial cultivars tested appear to grow well in the Northeast US. Among accessions tested, high levels of condensed tannins do not appear to be correlated with poor agronomic performance. BFT hay was 50-60 % birdsfoot trefoil, and 40-50 % weeds. Perennial weed control remains a challenge for organic producers, necessitating new planting, cover crop, and management strategies to sustain good stands. Analysis of Proanthocyanidins suggests that these compounds may not be the only bioactive compounds in BFT. Variation in the ratio of catechins:gallothechins in BFT accessions varying in anthelmintic efficacy may provide a focus for future work. Objective 2) An in vitro assay evaluating exsheathment and L3 viability in an aqueous extract of BFT strains was completed using 13 BFT strains. Six of the 13 strains were commercially available in the US. Efficacy ranged from 0 to 75% exsheathment inhibition, and 17 to 92% L3 mortality at a concentration of 25 mg/mL (BFT extract); however efficacy of aqueous extracts was not correlated with proanthocyanidin content. In vivo exsheathment of *Haemonchus contortus* larvae within the rumen was determined using four fistulated ewes and 2000 *H. contortus* L3 contained within capsules suspended in the rumen for eight hours. Feeding BFT hay did not inhibit L3 exsheathment in the rumen. A feeding trial was conducted with hay from five varieties of BFT produced in summer of 2016. Fourteen lambs were experimentally infected with *H. contortus* and fed either BFT or control hay for 6 weeks. There was an apparent decrease in fecal egg count in lambs fed BFT hay. Objective 3) A replicated trial at WVU compared lambs grazing a low-tannin BFT cultivar (Norcen) and a moderately high-tannin cultivar (Pardee) versus a conventional pasture of orchard grass and red clover; using an avoidance grazing (3-day) versus a challenge grazing (7-day) rotation. Lambs grazed for approximately 120 days in 2014, 2015, and 2016, and for 60 days in 2017. Differences in lamb fecal egg count, body condition or weight gain between high and low tannin cultivars were variable, and were usually not statistically significant, however lambs tended to perform better on both trefoil cultivars than on the conventional orchard grass pastures. Lambs on the challenge grazing rotation generally did not differ significantly from those on the avoidance grazing rotation. The proportion of lambs that retained organic status at the end of the grazing trial was 33 % for orchard grass/red clover pastures, but 60 % for BFT. Organic status also was significantly greater for lambs on the avoidance grazing rotation than the challenge grazing rotation. Lambs from 2017 gained better on BFT pastures than on orchard grass, but showed no difference in % Organic lambs, Fecal Egg Counts, or FAMACHA scores. This may have been due to the shorter grazing period, or to a low BFT content of pastures (2-4 %) compared to previous years. Objective 4) Eight Northeast farmers who had established BFT demonstration pastures during 2015 or 2016 were able to conduct valid 8-wk. on-farm grazing trials during the 2017 growing season comparing lamb performance on BFT pastures versus other forages. Lamb weight gain was significantly better on BFT pastures than on conventional pastures for five of eight growers. Animals on BFT pastures were getting better nutrition than their cohorts on control (various other forage) pastures, so it is unclear whether improvements are due to specific compounds in BFT that are antagonistic to worms, to improved immunity, or to effects of better nutrition contributing to parasite tolerance. Objective 5) Five introductory goat and sheep parasite workshops, 41 workshops or field days, and 34 small ruminant integrated parasite control / FAMACHA Training workshops have been conducted as project outreach since Sept 1, 2013. Approximately 1523 people attended these events and 668 people became certified in FAMACHA. Participants in FAMACHA workshops showed improvement in before-and-after quizzes to measure their knowledge of worm life cycles, evasive grazing practices and research on the possible role of high tannin forages and/or copper oxide wire particle oral dosing in worm control. A sampling of participants indicated that ~20% were interested in possibly planting BFT. A follow up survey to evaluate practices adopted or improved as well as economic and production impacts was distributed in March 2017. Past program participants (553) were invited to participate in this survey, and 138 surveys were completed. The pasture management changes most adopted by respondents because of attendance at our workshops were increasing the pasture rest period and height of pasture during their pasture rotations. The pasture management practices most often cited as ones they planned to make were planting and grazing annual forages such as small grains and brassicas (58%) or planting and grazing a high tannin forage such as BFT (61%). Ninety four respondents indicated that they learned more about the potential of high tannin forages to suppress worm infections in small ruminants, 13 indicated that they had planted a high tannin forage as a result of the workshops. Objective 6) The primary form of outreach has been the 80 workshops conducted through the project that discusses the on-farm

BFT grazing studies. The project resources developed during 2014 and 2015 continue to be distributed at workshops and field days and maintained on the project website at <http://web.uri.edu/sheepngoat/orei-resources/>. These resources include: Project Informational Flyer, BFT Establishment Fact Sheet and recordkeeping form, updated Case Studies on planting and establishing BFT organically. Objective 7) Fifty two respondents to the March 2017 survey indicated that they reduced their use of synthetic dewormers as a result of practices they adopted or improved upon because of our programs. Reported annual savings in dewormer costs ranged from \$30 to \$500, averaging \$143. Although a third of the farmers reported improved animals performance, only a few provided monetary values for this improvement. When reported, earnings from improved animal productivity ranged from \$100 to \$1400 (average \$557), savings in health costs (vet bills, labor to treat parasitized animals) ranged from \$100 to \$1000 (average \$300), and savings from reduced animal mortality ranged from \$400 to \$2000 (average \$1180). Three farms indicated that as a result of adoption of these practices they have reduced the number of animals they have to remove from their organic marketing channels while 52 farms reported that they have seen a reduction in the number of animals they have to deworm or the number of times a year they have to deworm. About 71% of respondents planning to raise goats or sheep reported increased confidence in their ability to cope with GIN parasites in their future flock because of our programs while 71% of veterinarians and educators also responded that they felt more confident advising goat and sheep farmers on GIN parasite management. Publications Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Stanton, Tatiana. L. and M.L. Thonney (2016). Integrated control of internal parasites in small ruminants In: Proceedings of the 22nd Annual Dairy Sheep Assoc. of North America Symposium, Ithaca, NY (2-4 Dec, 2016). Pages 81-89. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Barone, C., Ferguson, S., Zajac, A., Brown, R., Reed, J., Krueger, C., Petersson, K. In vitro screening of the anthelmintic efficacy of birdsfoot trefoil commercial varieties and cultivars against ovine *Haemonchus contortus*. American Society of Animal Science Joint Annual Meeting (ASAS JAM), Salt Lake City, Utah, July 18-22, 2016. Abstract No 699. Oral Presentation. Type: Websites Status: Published Year Published: 2016 Citation: website, Northeast Small Ruminant Parasite Control at <http://web.uri.edu/sheepngoat/orei/>. Type: Journal Articles Status: Submitted Year Published: 2017 Citation: Garza, J.J., S. P. Greiner, S.A. Bowdridge. 2017. Ovine neutrophils bind and impair *H. contortus* third-stage larvae in a breed and infection status-dependent manner requiring vital NET formation. *Parasit. Immunol.* Submitted Type: Journal Articles Status: Submitted Year Published: 2017 Citation: Mata-Padrino, D.J., D.P. Belesky, C.D. Crawford, B. Walsh, S.A. Bowdridge. 2017. Effects of grazing birdsfoot trefoil-enriched pasture on managing *Haemonchus contortus* infection in Suffolk crossbred lambs. *J. Anim. Sci.* Submitted Type: Journal Articles Status: Published Year Published: 2017 Citation: Garza, J.J., S.P. Greiner, S.A. Bowdridge. 2017. Serum-mediated *H. contortus* larval aggregation differs by larval stage and is enhanced by complement. *Parasit. Immunol.* 39:e12409. Type: Journal Articles Status: Published Year Published: 2017 Citation: Shepherd, E.A., J.J. Garza, S.P. Greiner, S.A. Bowdridge. 2017. Effects of ovine peripheral blood mononuclear cells on *Haemonchus contortus* larval death in vitro. *Parasit. Immunol.* 39:e12424

Progress 09/01/15 to 08/31/16 Outputs Target Audience: The Target Audiences in Year 4 were sheep and goat producers in the Northeast US. Specifically, we continued field testing trefoil pastures with four producers in 2016 to manage parasites in sheep or goats. Nine parasite workshops and four grower presentations were held from Oct. 2015 to September 2016. Over 200 people participated in the workshops. Seventy three people received FAMACHA certification. Two field days focusing on organic management of sheep and goats and forage management to reduce parasite infection in sheep and goats were held during 2016. Workshops on alternative forages with potential to assist in parasite management were also taught by participating researchers and farmers. Changes/Problems: UR lost the midsummer harvest of the six commercial varieties of BFT grown under organic management due to unexpectedly heavy rainfall on the freshly cut BFT. No further harvesting of BFT was possible in 2016 due to drought. We missed the June flowering on the seed production plots due to delay in obtaining bumblebees. Plants were clipped, and flowered again in August, but seed set was low due to heavy leafhopper presence and drought stress. Although the BFT stands were productive, Canada thistles were a problem on one farm resulting in the stand having to be mowed 3 days before the grazing study commenced and again during the study to prevent the thistles from going to seed. Another farm also opted to mow during their grazing trial the BFT stand was getting too mature. However, regrowth was rapid at both farms. Worms were absent at another farm. A major problem occurred at a farm where yearling goats were pulled from a good sized herd traditionally grazing 4 acres of diverse forage every 4 days for multiflora rose and barberry control in cattle pastures. The yearlings were not content to intensively graze small paddocks of BFT for 4 day periods. Instead two jumpers eventually led the entire treatment group to escape from the paddocks regularly and the study had to be halted. Drought caused most of the participating farmers to spend more time on their flocks during the summer and therefore did not conduct a field day. These farmers have committed to making presentations at winter conferences and/or producer meetings. Clear evidence for, and analysis of, the specific bioactive compounds in BFT has not been elucidated. Previously reported assays for nematode control efficacy were found to be impractical, however new assays have been developed. Work in this area will continue in 2017. What opportunities for training and professional development has the project provided? Graduate and undergraduate

students at WVU, URI and Cornell have obtained hands-on training in organic sheep management, FAMACHA and Body Condition Scoring, and analysis of Fecal Egg Counts. Seventy three participants in our Integrated Parasite Control / FAMACHA® Training workshops from January through July 2016 in NY and RI received FAMACHA certification. One of the on-farm grazing trials took place at a farm learning center where four farm interns were trained to take fecal samples and FAMACHA score goats. The List serv, BIRDSFOOTTREFOILFARMERSTUDY-L@cornell.edu was established in April 2014 to assist communication among the on-farm study farmers, extension staff and researchers with experience managing BFT test plots and grazing trials. Some of the farmers are organic inspectors or grazing consultants. Topics for 2016 have included frost seeding and assessing drought conditions in the region and its impacts on grower plots. How have the results been disseminated to communities of interest? Papers on the anthelmintic efficacy of birdsfoot trefoil and immunological responses of sheep were presented at the American Society of Animal Science Joint Annual Meeting, July 18-22, Salt Lake City, Utah. Current project activities and/or preliminary results were disseminated to Northeast sheep and goat farmers and educators at 11 parasite workshops and 2 field days throughout the project year. Updated, preliminary results from on-farm grazing trials are available online to farmers through our project website at <http://web.uri.edu/sheepngoat/orei-resources/>. What do you plan to do during the next reporting period to accomplish the goals? What do you plan to do during the next reporting period to accomplish the goals? URI will harvest BFT for hay during the summer of 2017. Based upon the feeding trial results with the fistulated ewes, it is anticipated that lambs infected with gastrointestinal nematodes, will be fed either control hay or the most promising commercial varieties of BFT to test for anthelmintic efficacy in vivo. Test an organic extract of the 45 BFT accessions and 6 commercial varieties using in vitro anthelmintic assays. Expand the seed production blocks using greenhouse-grown plants from seed harvested in 2016, and are planning to harvest seed again in 2017 Wisconsin will continue analysis of condensed tannins in birdsfoot trefoil accessions. WVU will repeat the replicated lamb grazing trial in BFT pastures. Cornell will statistically analyze the data from ten on-farm grazing trials that took place in 2015 and 2016. Conduct 2017 grazing trials with 2 farms frost seeding BFT. Present preliminary results from the BFT on-farm grazing trials at the Dairy Sheep Assoc. of North America 22nd Symposium on Dec 2-4, 2016, Cornell Univ., Ithaca, NY. IPM workshops, field days, and other conference presentations are planned for 2017. Continue to maintain and update project website with new resources and events including detailed progress bulletin and more conclusive results from the on-farm case studies. Publish preliminary results in farmer newsletters and magazines. Summarize results from the follow up survey sent out in spring/summer 2016. Administer the follow-up survey during spring/early summer 2017 to the 2016 program participants to document changes in producer behavior and project impacts and outcomes, and summarize the results in late summer. Project Directors will organize a final meeting with the farmers participating in our grazing trials to share research results from the research institutes (URI, WVU, Univ. of Wisconsin - Madison) Develop an extension fact sheet summarizing the results from the BFT on-farm grazing studies. Publish results from these studies. Impacts What was accomplished under these goals? Objectives 1) Evaluate birdsfoot trefoil cultivars to assess agronomic characteristics and tannin contents, identify which condensed tannins are critical for anthelmintic activity and characterize the structure/function relationship of the tannin profiles. Winter survival data were collected on the BFT nursery. The late winter/early spring of 2016 was extremely harsh for plants, with extreme freeze events in February and April, and most accessions suffered extensive losses. Seed production blocks were established for PI 193725, PI 325379, and a mixed population of accessions that had shown high efficacy and good agronomic performance. Seed was harvested from all blocks, but yields were low due to drought. Analysis of Proanthocyanidins suggests that these compounds may not be the only bioactive compounds in birdsfoot trefoil. Suppression of gastrointestinal nematodes appears to be correlated with reactivity with proteins. Assays based on the 8-terminal flavan unit may not be well correlated with bioactivity. For example, the cultivar Bruse has high levels of proanthocyanidins (condensed tannins), but performed poorly on nematode assays. 2) Assess the effects of high tannin forages on the larval and adult nematode response in vitro and in vivo, and measure key immune responses of the host animal; The protocol for in vivo larval exsheathment assay using the fistulated ewes has been completed. A feeding trial of 3 commercial varieties of BFT plus a control is underway. It is expected to be completed during the 2016/2017 winter. Expression of IL-4 was detected in resistant hair sheep, but not in susceptible wool sheep, indicating that upregulation of associated genes may be associated with mechanisms that reduce establishment of nematode parasites. 3) Evaluate herd health and economic outcomes of pasture mixes with high-tannin birdsfoot trefoil for suppression of intestinal parasites. Outreach and Extension Objectives: A replicated trial at WVU compared lambs fed a low-tannin cultivar (Norcen) and a moderately high-tannin cultivar (Pardee) to a conventional pasture of orchard grass and red clover; using an avoidance grazing (3-day) versus a challenge grazing (7-day) rotation. Differences in lamb fecal egg count, body condition or weight gain between high and low tannin cultivars were not statistically significant in 2014 or 2015, however the challenge grazing rotation, as expected, resulted in lambs with lower body condition and lower body weight, compared to the avoidance grazing rotation. In 2016, Body condition and weight were significantly greater, and Famacha scores were lower, for lambs on birdsfoot trefoil cultivars than on orchard grass/red clover at most dates. Fecal Egg Counts in 2016 usually did not differ significantly, and there were few differences

between lambs on the 3-day versus 7-day grazing rotations. After 3 years of trials, the proportion of lambs that retained organic status at the end of the grazing trial was 33 % for orchard grass/red clover pastures, but 60 % for birdsfoot trefoil. Trials at grower farms in 2015 showed lamb weight gain was equal to or better than on conventional pastures, however fecal egg counts and FAMACHA scores did not differ significantly. Data from the 2016 trials are being analyzed. 4) Demonstrate the real-world potential to reduce parasite burden in small ruminants through on-farm comparisons of pastures with and without birdsfoot trefoil forages; Four Northeast farmers (NY) who had established BFT demonstration pastures during 2015 conducted 8 wk. on-farm grazing trials during the 2016 growing season comparing performance on BFT pastures versus other forages. Project staff collected fecal egg counts, live weight changes, FAMACHA scores and any health interventions required (deworming etc.) in addition to evaluating the forages. One farm that frost seeded BFT in 2014 and 2015 delayed their grazing trial one year due to severe drought conditions. 5) Promote grower adoption of organic parasite control practices through IPM workshops, field days, and presentations at grower organizations, and document changes in grower behavior; Four Integrated Parasite Control / FAMACHA® Training workshops were conducted from January through July 2016 in NY and RI. Approximately 79 farmers, youth, livestock extension educators and veterinarians attended these workshops; Seventy three participants received FAMACHA certification. A pre and post test was administered to workshop participants to track changes in knowledge. Average scores increased from 51 % to 76%. Forty four percentage of respondents at the FAMACHA training in RI indicated that they planned to implement at least one new practice besides FAMACHA scoring as a result of the training. Seven parasite presentations or workshops targeting goat and sheep farmers were conducted in NY, RI and VT. Both URI and WVU organized summer field days in 2016 for farmers to tour the BFT plots/pastures and learn about ongoing research . 6) Use traditional outreach tools such as short fact sheets, and articles in agriculture and livestock publications of interest to growers, as well as electronic media such as eXtension and eOrganic to develop Communities of Practice and provide results to growers, crop advisors, Extension agents, and others; The project resources developed during 2014 and 2015 continue to be distributed at workshops and field days and maintained on the project website at <http://web.uri.edu/sheepgoat/orei-resources/>. These resources include: Project Informational Flyer, BFT Establishment Fact Sheet and recordkeeping form, updated Case Studies on planting and establishing BFT organically. 7) Assist farmers to realize increased earnings by documenting four criteria among participating growers: a) reduced use of synthetic dewormers, b) increased animal productivity attributed to lower worm loads, c) reduced number of animals removed from organic marketing channels because of dewormer intervention and d) successful transition from conventional to organic farming due to increased confidence in coping with parasite issues. A follow up survey of 41 questions to evaluate practices adopted or improved as well as economic and production impacts was developed and finalized by Cornell and URI during the winter 2016. Cornell issued an email invitation in March 2016 to 553 program participants throughout the Northeast who had provided contact information and had had sufficient time to begin implementing new parasite control practices and/or document improvements as a result of their education. Publications Type: Journal Articles Status: Submitted Year Published: 2016 Citation: Shepherd, E.A., J.J. Garza, S.P Greiner, S.A. Bowdridge. 2016. Effects of ovine peripheral blood mononuclear cells on *Haemonchus contortus* larval death in vitro. *Parasit. Immunol.* In review Type: Journal Articles Status: Accepted Year Published: 2016 Citation: Garza, J.J., S.P. Greiner, S.A. Bowdridge. 2016. Serum-mediated *H. contortus* larval aggregation differs by larval stage and is enhanced by complement. *Parasit. Immunol.* In revision. Type: Journal Articles Status: Published Year Published: 2016 Citation: Jacobs, J.R., K.N. Sommers, A.M. Zajac, D.R. Notter, S.A. Bowdridge. 2016. Early IL-4 gene expression in abomasum is a critical difference in resistance to *H. contortus*. *Parasit. Immunol.* 38:333-339. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Barone, C., Ferguson, S., Zajac, A., Brown, R., Reed, J., Krueger, C., Petersson, K. In vitro screening of the anthelmintic efficacy of birdsfoot trefoil commercial varieties and cultivars against ovine *Haemonchus contortus*. American Society of Animal Science Joint Annual Meeting (ASAS JAM), Salt Lake City, Utah, July 18-22, 2016. Abstract No 699. Oral Presentation. Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Garza, J., S.A. Bowdridge. 2016. Serum induces *H. contortus* larval aggregation via complement and antibody complexes that differ by larval stage. 61st Annual Meeting AAVP San Antonio, TX Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Garza, J., S.A. Bowdridge. 2016. *Haemonchus contortus* induced neutrophil extracellular trap formation differs between resistant and susceptible breeds of sheep. 61st Annual Meeting AAVP San Antonio, TX Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Garza, J., S.A. Bowdridge. 2016. *Haemonchus contortus* fourth stage larval excretory/secretory protein inhibits serum-mediated larval aggregation. 61st Annual Meeting AAVP San Antonio, TX Type: Conference Papers and Presentations Status: Published Year Published: 2016 Citation: Jacobs, J., S.A. Bowdridge. 2016. Interleukin-4 and its downstream targets are rapidly upregulated in immune cells of St. Croix sheep exposed to *H. contortus* larval antigen in vitro. 61st Annual Meeting AAVP San Antonio, TX Type: Conference Papers and Presentations Status: Accepted Year Published: 2016 Citation: Russ, B., J. Garza, S.A. Bowdridge. 2016. Isolation of third stage *H. contortus* cuticle and cuticle protein. 61st Annual Meeting AAVP San Antonio, TX Progress 09/01/14 to 08/31/15 Outputs Target Audience: The Target Audiences in Year3

were sheep and goat producers in the Northeast US. Specifically, we started field testing trefoil pastures with six producers in 2015 to manage parasites in sheep or goats. Sixteen parasite workshops were held from Dec 2014 to October 2015. Over 404 people participated in the workshops. Fifty three people received FAMACHA certification. Five field days focusing on organic management of sheep and goats and forage management to reduce parasite infection in sheep and goats were held during 2015. Three workshops on alternative forages with potential to assist in parasite management were also taught by participating researchers and farmers.

Changes/Problems: We were only able to take one cutting of BFT for hay last year due to unavailability of haying equipment in early August. Designing a container that can be suspended in the rumen to securely contain the ensheathed larva but still allow for free flow of rumen "juices" has been problematic. Previously reported methods in the literature result in a high percentage of escaped larvae and ultimately result in an infected fistulated ewe. We are close to solving this issue. Grazing trials at WVU have been delayed by poor stand establishment in 2014. BFT stands in 2015 were substantially improved, and we expect a full complement of replicates in 2016. As anticipated, there have been some challenges and concerns for the 11 demonstration farms. Problems have included animal loss from predators, extremely low worm populations during the grazing study, difficulty providing a similar group of control animals, low BFT yields because of adverse weather challenges and/or compulsions to mow the BFT stands in the midst of the grazing study. Six farms conducted grazing trials in 2015. However, the amount of BFT available for animals to consume was limiting on two farms and worms were absent on another farm, leaving 3 farms with good parameters for comparison.

What opportunities for training and professional development has the project provided? Eight Integrated Parasite Control / FAMACHA Training workshops provided training on integrated parasite management and FAMACHA certification to 149 people from November 2014 to October 2015. Approximately 200 farmers, youth and extension livestock educators attended introductory parasite management workshops (4), field days (6) or symposium presentations (1) providing information on innovations in sheep and goat parasite management and showcasing project activities. Many of the workshops included training in fecal worm egg identification and counting. The 2015 grazing trials provided opportunities for 3 Cornell undergraduates to become proficient at quantitatively analyzing and reporting small ruminant fecal samples including how to do highly specialized PNA assays using a lectin binding stain. One Cornell undergraduate obtained an extension internship to learn agronomy field evaluation techniques while working side by side with extension field staff at two of the demonstration farms. However, funding for these students was provided by cosponsors of the project rather than OREI. The Listserv, BIRDSFOOT TREFOIL FARMER STUDY-L@cornell.edu was established in April 2014 to assist communication among the on-farm study farmers, extension staff and researchers with experience managing BFT test plots and grazing trials. Some of the farmers are organic inspectors or grazing consultants. Thus the interchange between farmers and staff has been very educational. Example topics for 2015 have included: fertility management, weed and nurse crop management, and effective seeding methods for the on-farm demonstration BFT pastures.

How have the results been disseminated to communities of interest? Dr. Tatiana Stanton, Cornell University is a member of the eXtension Goat Industry team and attended a meeting in February 2015 at Tuskegee University, Alabama. Dr. Stanton updated the resources section with the OREI project website and will expand sections on the role of forage management in small ruminant parasite control, incorporating resources and knowledge gained by this grant project with assistance from project partners at URI and Virginia Tech. URI presented a poster on the anthelmintic efficacy of commercial varieties and cultivars of birdsfoot trefoil against *Haemonchus contortus* at the 2015 Annual Meeting of the American Association of Veterinary Parasitologists, July 2015, Boston, MA. Dr. Stanton presented a research report on parasite management in sheep and goats that included information on planting and establishing Birdsfoot trefoil organically on two of the demonstration farms at the Eastern Northern NY Ag. Dev. Program Annual Meeting, Miner Institute, Feb 27, 2015, Chazy, NY. 26 participants, mostly extension agronomy educators and farmers. Fifteen Cornell Cooperative Extension livestock educators participated in a November 2014 In-Service Training that included a 1 ½ hr. session on "innovations in sheep goat parasite management" where the rationale for this BFT project and problems encountered in establishing BFT organically were discussed in depth. Cornell Univ. presented preliminary results from one on-farm study comparing effects of grazing BFT and/or dosing with COWP on worm counts and lamb performance during the Northeastern IPM Center's First Annual Online Conference, Oct 20, 2015. 20 speakers, 100+ online participants. Current project activities and/or preliminary results were disseminated to sheep and goat farmers at 12 parasite workshops and 7 field days throughout the project year.

What do you plan to do during the next reporting period to accomplish the goals? It is anticipated that BFT feeding trials using the fistulated ewes will begin in January 2016. Based upon the feeding trial results with the fistulated ewes, it is anticipated that lambs, experimentally infected with *Haemonchus contortus*, will be fed either control hay or the most promising commercial varieties of BFT to test for anthelmintic efficacy in vivo. An organic extract of the 45 BFT accessions and 6 commercial varieties will be tested using in vitro anthelmintic assays. The grazing trials at WVU will be repeated in 2016, and immunological assays will be conducted at WVU using condensed tannin extracts. We will analyze and summarize 2015 data for the 6 on-farm grazing trials and the 5 new BFT seedings. and conduct 2016 grazing trials with the 5 farms that

seeded BFT during 2015. Sustainability of BFT plantings from the 6 farms where BFT was established in 2014 and grazed in 2015 will be assessed. We hope to repeat grazing trials on two farms that participated in grazing trials in 2015. IPM workshops, field days, and other conference presentations are planned for 2016. Preliminary results will be published in farmer newsletters and magazines. A follow-up survey to program participants will be administered to document changes in producer behavior and project impacts and outcomes. Impacts What was accomplished under these goals? Objective 1. Field evaluation of accessions at URI is continuing, and approximately 2000 pounds of Birdfoot trefoil (BFT) hay from six commercial varieties was harvested in 2015 for lamb feeding trials. UWisconsin has isolated 3.5 g of tannin extract from the variety Bruce for use in immune and in vitro assays. Objective 2, URI has placed rumen fistulas in four ewes and is continuing development of in vivo assay methods to be used for feeding trials in 2016. In vitro assays assess anthelmintic efficacy, egg hatch and L1/L2 mortality were conducted on an aqueous extract of forty-five BFT accessions and six commercial varieties. Anthelmintic efficacy differed among varieties at 3 mg/ml. Using aqueous extracts of BFT powder, egg hatch inhibition at 3 mg powder/ml ranged from zero to 100 %, and one BFT variety induced 100 % inhibition at 0.75 mg/ml but there was no correlation between inhibition of egg hatch and the DMAC concentration of condensed tannins in the freeze-dried BFT powder. Objective 3. A replicated trial at WVU compared lambs fed a low-tannin cultivar (Norcen) and a moderately high-tannin cultivar (Pardee) to a conventional pasture of orchard grass and red clover; using an avoidance grazing (3-day) versus a challenge grazing (7-day) rotation. Differences in lamb fecal egg count, body condition or weight gain between high and low tannin cultivars were not statistically significant in 2014 or 2015, however the challenge grazing rotation, as expected, resulted in lambs with lower body condition and lower body weight, compared to the avoidance grazing rotation. Trials at three grower farms showed lamb weight gain was equal to or better than on conventional pastures, however fecal egg counts and FAMACHA scores did not differ significantly. Objective 4. Six Northeast farmers established BFT demonstration pastures in 2014 and conducted on-farm grazing trials in 2015. Five additional growers established BFT demonstration pastures in Spring 2015 and all will compare lamb or goat performance on BFT pastures versus conventional pastures. Lower FAMACHA scores and improved weight gain occurred with BFT pastures, but data have not yet been analyzed statistically (http://web.uri.edu/sheepngoat/files/NYdemofarms_BFTstudy_2014-2015.pdf). Objective 5. Eight Integrated Parasite Control / FAMACHA Training workshops were conducted from January through October 2015 in PA, NY, VT and RI. Approximately 150 people participated in these workshops. Pre and post quizzes to measure changes in knowledge about integrated parasite management were completed by participants at five of the workshops. Average before and after results for the percentage of questions answered correctly changed from 55.2% to 77.5%. Participants completed post quiz evaluations in three VT, one RI and one NY FAMACHA workshops. Approximately 41%, 42%, 55%, 59% and 60% of the participants, respectively, plan to adopt parasite management practices as a result of attending the workshops including implementing or improving FAMACHA scoring, fecal egg counting, selective deworming and smart drug use, as well as several pasture management practices including improved rotation, lower animal density, mixed species grazing, and use of condensed tannin forages. Seven field days or case study presentations were conducted in NY, RI and WV focusing on current project research and preliminary results from grazing trials at demonstration farms. Objective 6. The project resources developed during 2014 continue to be distributed at workshops and field days and maintained on the project website at <http://web.uri.edu/sheepngoat/orei-resources/>. These resources include: Project Informational Flyer, BFT Establishment Fact Sheet and recordkeeping form, Case Studies on planting and establishing BFT organically showcasing 4 project demonstration farms. The project website is continually updated and maintained with resources and events. A detailed progress bulletin summarizing all project research and extension activities to date has been drafted and is awaiting completion of the 2015 growing season research activities for final development. It will be posted on the project website and circulated to demonstration farms and producer listservs and email networks. Objective 7. A follow up survey to evaluate practices adopted or improved as well as economic and production impacts has been drafted by Extension staff. It will be completed and administered during Winter 2016 to those program participants who have agreed to provide contact information (total to date ~452 participants - will be fewer once we edit for duplicates and members of the same farm), and who have had sufficient time to begin implementing new parasite control practices and/or documenting improvements as a result of their education. The survey can be administered online, or in hard copy format or by phone if preferred by the producer. Publications Type: Conference Papers and Presentations Status: Published Year Published: 2015 Citation: Barone, C., Ferguson, S., Brown, R., Zajac, A., Reed, J., Petersson, K. Anthelmintic efficacy of commercial varieties and cultivars of birdsfoot trefoil against *Haemonchus contortus*. Association of Veterinary Parasitologists (AAVP), Boston, MA, July 11-14, 2015. Abstract No. 94. Poster presentation. **PROGRESS: 2013/09 TO 2014/08** Target Audience: The Target Audiences in Year 2 were sheep and goat producers in the Northeast US. Specifically, we surveyed 12 sheep producers to serve as participants in field testing in 2015, and hosted a range of workshops. Eighteen parasite workshops were held from Dec 2013 to Nov 2014. Approximately 379 people participated in the workshops. One hundred people received FAMACHA certification. Two field days focusing on organic management of sheep and goats and forage management to reduce parasite

infection in sheep and goats were held during 2014. Three workshops on alternative forages with potential to assist in parasite management were also taught by participating researchers and farmers. The presentations are available on the web at <http://www.ansci.cornell.edu/goats/CSGSymposium/index.html>. Changes/Problems: Because of poor stands in some plots at WVU, only two replicates were used for the grazing study in 2014, and the proportion of BFT in some plots was relatively low. This may have limited any treatment effect. Plots were replanted in fall, 2014, and we expect to have all three replicates in 2015. As a result, an additional greenhouse experiment was developed to better compare condensed tannin concentration among commercial cultivars. Delays in isolating adequate amounts of condensed tannins have delayed immune response studies at WVU, but we anticipate having these underway in 2015. Planting of BFT for on-farm studies was delayed a year into the study because of problems with research test plots. Originally we planned to conduct 16 on-farm grazing trials. We have four additional farmers interested in joining the on farm studies and planting BFT in 2015. However, we need to decide whether to involve them or instead plan on having presently participating farms conduct repeat grazing trials in 2016. What opportunities for training and professional development has the project provided? Two graduate students traveled to the University of Wisconsin for a week-long hands-on training in the preparation and analysis of condensed tannin extracts in the laboratory of Dr. Jess Reed, a collaborator on this project. Dr. Katherine Petersson, also traveled to UW for several days to observe the extraction procedures and meet with Drs. Reed and Krueger on coordinating the BFT extraction phase of these studies. Four researchers, two graduate students, and two staff attended the Cornell Sheep and Goat Symposium, participating in workshops and professional development in pasture management, and sheep health workshops. Grower IPM workshops provided training on intestinal parasite management to approximately 379 people from Dec 2013 to Nov 2014. One hundred participants received FAMACHA certification. The List serv, BIRDSFOOTTREFOILFARMERSTUDY-L@cornell.edu was established in April 2014 to assist communication among the on-farm study farmers, extension staff and researchers with experience managing BFT test plots and grazing trials. Some of the farmers are organic inspectors or grazing consultants. Thus the interchange between farmers and staff has been very educational. Example topics have included: historic distribution of BFT *Fusarium* wilt in the Northeast US; addressing low soil P availability issues organically; using prilled lime, millet or killed (roasted) seed of similar size to solve seed volume problems when broadcasting BFT seed; sourcing organically approved lime applicators; on line lime calculators to determine actual ENV rates applied, etc. How have the results been disseminated to communities of interest? A preliminary research report was presented at the Crop Science Society of America annual meeting. Research results were presented in oral presentations by Dr. Jim Kotcon, Dr. Katherine Petersson, Dr. Tatiana Stanton, and Dr. Anne Zajac at the WVU Organic Farm Field Day, and at the Cornell Sheep and Goat Symposium. Results of previous work have been disseminated in grower workshops and field days as noted previously. The eXtension Goat Industry meeting will take place Feb. 17-19, 2015 in Alabama at Tuskegee University. Dr. tatiana Stanton will be attending. In the past she helped develop and edit the Goat Industry's parasite management resources. During 2015, she plans to expand sections on the role of forage management in small ruminant parasite control incorporating the resources this grant project has developed thus far. She will also be expanding sections on the role and considerations of copper oxide wire particles in barber pole worm management programs. What do you plan to do during the next reporting period to accomplish the goals? In 2015, we will collect a third year of agronomic performance data from the URI nursery, and produce seed from the most promising accessions. URI will also evaluate grazing tolerance and possibly feeding preference for sheep using the grazing trial pasture. In addition, sufficient hay will be produced to conduct in vivo analysis of anthelmintic efficacy on fistulated sheep. Due to the extensive amount of time required for freeze drying the various accessions of BFT prior to the preparation of an extract, BFT whole leaf and whole leaf powder will be tested for anthelmintic efficacy using the egg hatch assay, artificial exsheathment and larval development via coproculture. This will serve as a screening method to help direct the selection of candidates for seed propagation as well as prioritization of candidates for preparation of condensed tannin extracts. Four sheep will be fistulated over the winter 2015 and preliminary feeding trials on the BFT hay collected during 2014 will be conducted. Due to the small volume of hay collected, varieties will be combined and tested as a group versus control hay to test the effect of BFT on the exsheathment of *Haemonchus contortus* infective larvae (L3). After the preliminary feeding trials with BFT in the fistulated sheep using composites of the hay produced in 2014, commercial hay varieties grown at URI and harvested during the 2015 season will be individually fed to the fistulated sheep to test the effect of BFT consumption on larval exsheathment in the rumen. At WVU, the large grazing trial will be repeated and expanded, with the goal of three complete replicates of each treatment and grazing interval. Data to be collected will include lamb weight gain, Fecal Egg Counts, FAMACHA, Body Condition Index, and proportion of lambs that reach market weight with organic status. Forages will again be analyzed for condensed tannin content to assess the role of season and grazing treatment on tannin concentrations. A large pasture of Bruce BFT has been established to produce BFT forage to assess the role of condensed tannins in immune responses of naïve lambs. In addition, a portion of these lambs will be assessed for intestinal worm burden at Virginia Tech. Identification of the bioactive fractions of condensed tannins will continue at UW. On-farm comparisons of internal parasite infection in lambs or kids grazing pastures with and

without birdsfoot trefoil forages are planned for Jul/Aug 2015 at 6 participating farms in New York and Maine that established BFT pastures in 2014. Another 5 farms will plant BFT during 2015. We have several invitations to conduct workshops on integrated parasite management in small ruminants throughout the Northeast US.

IMPACT: 2013/09 TO 2014/08 What was accomplished under these goals? Impacts: This project is in early phases, impacts have been associated with preliminary results at research sites. Growers interested in organic sheep and goat production have demonstrated sustained interest in use of high-tannin forages to manage parasites, and 11 growers are now planting birdsfoot trefoil (BFT) pastures for on-farm grazing evaluations in 2015. Because BFT is slow to establish, research results are still preliminary. Progress and activities: Objective 1) Evaluate birdsfoot trefoil cultivars to assess agronomic characteristics and tannin contents, identify which condensed tannins are critical for anthelmintic activity and characterize the structure/function relationship of the tannin profiles We collected a second year of agronomic performance data at University of Rhode Island (URI) for accessions in the nursery. We harvested and froze sufficient leaf tissue of all of the accessions and commercial varieties to produce 1 kg freeze-dried tissue of each accession/variety. Freeze drying is in progress. A second hay field with 6 commercial varieties was established at URI, bringing the total hay acreage to ~ 1 acre per variety. We harvested 2 cuttings of hay from the original field established in September 2012. We established a grazing trial using the 20 best accessions from the nursery and all of the commercial varieties. This trial will be used to evaluate grazing tolerance of the accessions. We repeated a grazing trial at West Virginia University (WVU) to evaluate management practices to control weeds and enhance stands of four commercial cultivars. Birdsfoot trefoil growth and production of condensed tannins were determined before and after grazing at WVU. Grazing and mowing both improved BFT stand density compared to unmanaged plots. Foliage samples from a WVU greenhouse trial were assayed for condensed tannins before and 7 days after an initial clipping using Near InfraRed Spectrometry to evaluate condensed tannin development in response to simulated grazing. We have isolated between 859.8 to 3,472.7 mg of proanthocyanidins (PAC) from Bruce at the University of Wisconsin (UW). We have not yet validated a BFT standard so we are using PAC A2, a dimer that is available from chemical suppliers, and a PAC standard that we isolated and validated from cranberries. We have also carried out MALDI-TOF MS on the isolated BFT PAC from Bruce and these spectra are very informative. In addition to the hetero-oligomers that contain both catechin and gallic acid monomers, there is another series that appears to be glycosylated with a pentose unit. We are ready to distribute the isolated PAC for use in vitro studies. Objective 2) Assess the effects of high tannin forages on the larval and adult nematode response in vitro and in vivo, and measure key immune responses of the host animal; We conducted a small feeding trial at URI with 4 sheep using the BFT hay harvested in 2014. Although, the sheep readily consumed the BFT hay, there was a negative correlation between the amount consumed and the percentage of BFT in the hay. A larval development assay using copro-culture was established, an in vitro larval development assay is under development at URI. Objective 3) Evaluate herd health and economic outcomes of pasture mixes with high-tannin birdsfoot trefoil for suppression of intestinal parasites. We conducted a large replicated grazing trial at WVU. Two ewes and their 4 lambs were grazed on a low-tannin BFT cultivar, Norcen; a moderately high-tannin cultivar, Pardee; or tannin-free pastures of orchard grass and red clover (OG/RC). Flocks grazed 2 replicates of each pasture for 3 or 7-day periods with 60 or 30-day return frequencies respectively. Forage mass was insufficient for the originally planned grazing duration, so sheep were moved to other pastures in 27 days instead of 60 until weaning, at which time lambs only were returned to the pasture for a second round of grazing. Lamb weight gain was greatest on pastures with the best BFT stands. Although Fecal Egg Counts and weight gain did not differ among pasture treatments or grazing duration, all 8 lambs on Pardee retained organic status at the end of the experiment, compared to only 6 of 8 lambs on Norcen and 4 of 8 on OG/RC. 4) Demonstrate the real-world potential to reduce parasite burden in small ruminants through on-farm comparisons of pastures with and without birdsfoot trefoil forages; Eleven Northeast growers from Maine and New York, interested in participating in the on-farm trials were surveyed. Extension and farmer involvement in the studies were reviewed. Growers have completed soil sampling and most have plantings underway, or will plant BFT in spring 2015. Ten of the participating farms attended a meeting for the OREI project on Oct. 3, 2014 in Ithaca, NY with extension staff and researchers. Researchers gave progress reports and all participants shared experiences planting BFT or preparing land. Requirements for the 2015 grazing trials were reviewed. 5) Promote grower adoption of organic parasite control practices through IPM workshops, field days, and presentations at grower organizations, and document changes in grower behavior; Approximately 379 people participated in parasite workshops held from Dec 2013 to Nov 2014, and 100 people received FAMACHA certification. Pre and post quizzes to measure changes in knowledge about innovations in integrated parasite management were completed by participants at some workshops. Before and after results for the percentage of questions answered correctly increased by an average of 15 % for 8 workshops. Participant evaluations were available from 4 other workshops, scores averaged 4.5 out of 5 possible points where 5 indicated "very useful". Two field days focusing on organic management of sheep and goats and forage management to reduce parasite infection in sheep and goats were held. Three workshops on alternative forages with potential to assist in parasite management were also taught by participating researchers and farmers. 6) Use traditional outreach tools such as short fact sheets, and articles in agriculture and livestock

publications of interest to growers, as well as electronic media such as eXtension and eOrganic to develop Communities of Practice and provide results to growers, crop advisors, Extension agents, and others; and OREI Flyer - Overview of the research project and rationale for the potential of BFT as a parasite management tool. Distributed to participants at all succeeding workshops including 200 attendees of the 2014 Cornell Sheep and Goat Symposium. BFT Establishment Fact Sheet and record form - 6-page fact sheet outlining the potential use of high tannin forages to reduce parasite infections, challenges to trying to establish and maintain relatively pure stands of BFT, overview of organic methods of growing and management and educational resources. Case Studies on planting and establishing BFT organically at 4 study farms - Portions of these case studies were presented at workshops during the 2014 Cornell Sheep & Goat Symposium. These resources are available at <http://web.uri.edu/sheepngoat/orei-resources/> 7) Assist farmers to realize increased earnings by documenting four criteria among participating growers: a) reduced use of synthetic dewormers, b) increased animal productivity attributed to lower worm loads, c) reduced number of animals removed from organic marketing channels because of dewormer intervention and d) successful transition from conventional to organic farming due to increased confidence in coping with parasite issues. Documentation will begin for growers for whom we have obtained contact information to follow up on farmer changes in behavior. Follow up contact info was obtained from 329 workshop participants in 2013 and 2014. PUBLICATIONS (not previously reported): 2013/09 TO 2014/08 1\ Type: Conference Papers and Presentations Status: Published Year Published: 2014 Citation: Uphold, R., J. Kotcon, T. Griggs, and E. Rayburn. 2014. Tannin content in birdsfoot trefoil in response to herbivory and season. Abstract, Crop Science Society of America Annual Meeting. available at: <https://scisoc.confex.com/scisoc/2014am/webprogram/Paper89371.html> 2\ Type: Websites Status: Published Year Published: 2014 Citation: Northeast Small Ruminant Parasite Control, at <http://web.uri.edu/sheepngoat/orei/>

PROGRESS

2012/09 TO 2013/08 Target Audience: Target audiences in Year 1 were primarily sheep and goat producers in the Northeast US. We conducted 10 integrated parasite management workshops including FAMACHA certification with NE goat and sheep farmers and veterinary staff and technicians from October 2012 through November 2013. The workshops covered parasite life cycles, dewormer options and methods, parasite monitoring techniques, and the principles of IPM, forage-based parasite control, dewormer resistance, and refugia maintenance. Recent innovations in parasite management such as evasive grazing techniques, the use of high tannin forages and copper oxide wire particles were also discussed. Most workshops also included hands-on fecal egg counting. Two on-farm field days were also conducted, one in New York, one at West Virginia University, focusing on new methods of parasite control. Participants at most of these workshops were asked to provide contact information if they were willing to participate further in the project, including monitoring parasite management practices, and participating in grower trials. Approximately 240 people participated in workshops at Cornell, URI, and WVU, of which approximately 150 provided their willingness to collaborate, an indication of the intense interest this project evokes among organic and transitional sheep producers. List of Small Ruminant Integrated Parasite Management Workshops included FAMACHA certification, hands-on fecal egg counting and discussion of innovative parasite management techniques, etc. Cornell Sheep and Goat Symposium 2012, Cornell Univ. Ithaca, NY Date: October 27, 2012 Time: 8:30 am to 2:15 pm Workshop leaders: Dr. Dwight Bowman, Dr. Steve Hart, Dr. tatiana Stanton (organizer) Participants:40 (primarily farmers) NOFA-NY Winter Conference, Saratoga Springs, NY Date: January 25, 2013 Time: 9 am to 4:30 pm Workshop leaders: Dr. Katherine Petersson, Dr. tatiana nStanton, Dr. Anne Zajac DVM Participants: 25 (3 veterinarians, remainder sheep and goat farmers) Katherine and Anne in New England Date: January 26, 2013Time: Workshop leaders: Dr. Katherine Petersson, Dr. Anne Zajac DVM Participants: Glynwood Farm Center, Cold Springs, NY Date: May 8, 2013 Time: Workshop leaders: Dr. tatiana Stanton Participants: 21 (1 veterinarian, remainder were farmers or farm interns from several farms) State University of New York Delhi, Delhi, NY Date: May 18, 2013 Time: 10 am to 2:30 pm Workshop leaders: Dr. tatiana Stanton Participants: 26 (9 farmers, 2 extension educators, 15 vet. tech students) Dighton, MA Date: June 22, 2013Time: Workshop leaders: Dr. Katherine Petersson and Holly Burdett Participants: 6 farmers Cornell Goat & Sheep Health Day, Cornell Univ., Ithaca, NY Date: Sept 21, 2013 Time: 9:15 am to 3 pm Workshop leaders: Dr. Dwight Bowman, Dr. tatiana Stanton, Dr. Michael Thonney Participants: 38 farmers Cornell Cooperative Extension (CCE) of Oneida County, Waterville, NY -- did not include hands-on fecal egg counting Date: Oct 12, 2013 Time: 10 am to 3 pm Workshop leaders: Dr. tatiana Stanton Participants: 11 (1 agricultural college student, 1 extension educator, 9 farmers) CCE of Otsego & Rensselaer Counties & the Leatherstocking Shepherds Assoc., New Berlin, NY Date: Oct 26, 2013 Time: 9:30 am to 3:30 pm Workshop leaders: Dr. Rachel Frazer, DVM and Dr. tatiana Stanton Participants: 17 (1 veterinarian, 1 extension educator, 15 farmers) WVU Sheep parasite Workshop, Morgantown, WV Date: nov. 2, 2013Time: 9:00 am to 4 pm Workshop leaders:Dr. Scott Bowdridge and Dr. David Belesky Participants:Approximately 30 Cornell University Veterinary College, Ithaca, NY - did not include hands-on fecal egg counting Date: Nov 10, 2013 Time: 1 pm to 4

pm Workshop leaders: Dr. tatiana Stanton Participants: 7 veterinary students focusing on small ruminants
Pasture Field Days on Parasite Management in Sheep and Goats no FAMACHA certification, focused on evasive grazing techniques, condensed tannin forages and methods to incorporate copper wire oxide particles use into an integrated program WVU Organic Research Farm Field day -- Morgantown, WV Date: Aug. 8, 2012 Time 1 pm to 7 pm Workshop and tour leaders: Dr. James Kotcon, Dr. David Belesky, Dr. Domingo Matapadrino
Participants: Approximately 120 total, of which the sheep workshops and tours attracted approximately 40 people.
Northeast Organic Farming Assoc. of NY (NOFA-NY) -- Field Day at Asgaard Goat Dairy Date: Aug 12, 2013
Time: 1 pm to 4 pm Workshop leaders: Dr. Dwight Bowman, Dr. tatiana Stanton, Rhonda Butler (farm owner), Betsy Hodge (extension educator) Participants: 16 farmers not including Asgaard farm interns and herds person, and NOFA extensionist
Changes/Problems: Initial grazing trials at WVU scheduled for 2013 were delayed to 2014 due to poor pasture establishment. Additional work is underway to identify improved agronomic management to encourage establishment using organic practices, as well as greenhouse trials to identify organic management approaches to optimize tannin concentrations in forages. What opportunities for training and professional development has the project provided? Two graduate students have begun Masters degree research as part of this project. Two additional students are planned to begin research in 2014. Grower IPM workshops provided training on intestinal parasite management to approximately 260 people in 2012-13. Seven presentations on "Innovations in Goat and Sheep Parasite Management" are planned for 2014. Interest in the project is reflected in the number of participants and the number of invitations for more presentations. How have the results been disseminated to communities of interest? Results of previous work have been disseminated in workshops and field days, as noted previously. Meetings are planned in 2014 to begin development of eOrganic outreach materials. What do you plan to do during the next reporting period to accomplish the goals? Initial grazing trials will commence at WVU in 2014, and pastures for on-farm trials will be seeded so that grazing may commence in 2015. Birdsfoot trefoil is slow to establish, and management practices to assure adequate stands in organic pastures will be evaluated. Extraction and identification of the active tannin components will be underway within the next few months, and adequate volumes of birdsfoot trefoil hay for feeding trials will be collected in summer 2014. A planning meeting is scheduled for february 2014 to evaluate results and make decisions on preferred birdsfoot trefoil cultivars to recommend for grower trials. Seven presentations on "Innovations in Goat & Sheep Parasite Management" are scheduled this winter in NY and PA during the Northern NY Sheep and Goat Week, the Stone Barn Young Farmer Conference, the Catskills Regional Agriculture Conference, the NOFA-NY Winter Conference and the Northeast Pasture Consortium Conference. Interest in the topic is reflected in the number of invitations that resulted in these engagements.

IMPACT

2012/09 TO 2013/08 What was accomplished under these goals? Objective 1) Evaluate birdsfoot trefoil cultivars to assess agronomic characteristics and tannin contents, identify which condensed tannins are critical for anthelmintic activity and characterize the structure/function relationship of the tannin profiles; At URI, 51 BFT accessions with potential for high condensed tannin levels were obtained from germplasm repositories and breeders. Seedlings were grown up in the greenhouse and transplanted into a field nursery. Germination rates were sufficient to establish 60 plants per accession in the nursery for 36 accessions. Another 10 accessions were incompletely replicated with 40 plants, and 5 with only 20 plants. Three accessions had extremely poor germination and were not transplanted. Efforts continue to establish additional plants, with the goal of having all accessions fully replicated for 2014. Data were collected on growth habit, height, width, flowering and leaf color, and these nursery plots were rated for tolerance to leafhopper. Samples were collected for tannin analysis, and cuttings of each accession were rooted for greenhouse trials in 2014. Seven quarter-acre plots were seeded at URI in September 2012 at a rate of 8 lbs per acre, along with a nurse crop of oats at 80 lbs/acre. We seeded one plot of each of the following: Empire, Bull, Bruce, Norcen, Pardee, Leo, and a New York landrace. The field was mowed repeatedly with the blade set just above the trefoil to suppress weeds. At WVU, small plots (8 by 100 feet) of cultivars Bull, Empire, Leo and Norcen established in 2012. In 2013 the plots were subdivided to assess pasture management effects on stand establishment. Plots either unmanaged or were grazed or mowed to manage weeds. Sheep favored grazing birdsfoot trefoil over weeds in all varieties, however regrowth after 30 days was better than in unmanaged controls. Mowing appeared to promote better stands and more regrowth than grazing. Greenhouse trials were established at WVU with cultivars Empire, Norcen, Pardee, and Grasslands Goldi, representing a range from low to high tannin concentrations respectively. Plants will be clipped on 30 and 60-day frequencies and tannin concentration of regrowth will be compared to unclipped controls to determine whether BFT responds to age or mowing by altering tannin levels in shoot tissue. 2) Assess the effects of high tannin forages on the larval and adult nematode response in vitro and in vivo, and measure key immune responses of the host animal; At URI, anthelmintic assays required by this project are in varying stages of optimization. The in vitro egg hatch assay and larval exsheathment assay have been optimized and the in vitro larval development assay is in the process of being optimized. Donor lambs have been experimentally infected

with *Haemonchus contortus* and are providing a ready supply of *Haemonchus contortus* eggs and infective larvae. The protocol for preparation of a crude condensed tannin extract of all BFT samples collected this summer is being optimized. At WVU, methods of cell separation and cell culture conditions were validated. Future experiments on immune responses will be conducted in 2014 as BFT hay and tannin extracts become available..

3) Evaluate herd health and economic outcomes of pasture mixes with high-tannin birdsfoot trefoil for suppression of intestinal parasites. Field-scale plantings of Birdsfoot trefoil were established at WVU and URI. At WVU, four replicate 1-care plots each of Birdsfoot trefoil cultivars Norcen (low tannin variety) and Pardee (moderately high tannin levels) as well as orchard grass/red clover controls were planted in spring 2013. Due to excessive rainfall, weed pressure was high in some plots leading to poor stands. Two reps may need to be re-planted in 2014, however the remaining two reps averaged 20-30 % BFT stand composition and will be used for grazing trials in 2014. Due to slow establishment of BFT pastures, grazing trials were postponed until 2014.

Outreach and Extension Objectives: 4) Demonstrate the real-world potential to reduce parasite burden in small ruminants through on-farm comparisons of pastures with and without birdsfoot trefoil forages; We conducted 11 integrated parasite management workshops including FAMACHA certification with NE goat and sheep farmers and veterinary staff and technicians from October 2012 through November 2013. These workshops covered parasite life cycles, dewormer options and methods, parasite monitoring techniques, and the principles of IPM, forage-based parasite control, dewormer resistance, and refugia maintenance. Recent innovations in parasite management such as evasive grazing techniques, the use of high tannin forages and copper oxide wire particles were also discussed. Most workshops also included hands-on fecal egg counting. . 5) Promote grower adoption of organic parasite control practices through IPM workshops, field days, and presentations at grower organizations, and document changes in grower behavior; We conducted 2 pasture field days on new methods of parasite control. Pre and post tests were completed by most participants at seven of the IPM/FAMACHA workshops. Workshop participants were also asked to provide their contact information if willing to let us track whether their parasite management practices changed after participating in the workshops. Approximately 260 people participated in the workshops 6) Use traditional outreach tools such as short fact sheets, and articles in agriculture and livestock publications of interest to growers, as well as electronic media such as eXtension and eOrganic to develop Communities of Practice and provide results to growers, crop advisors, Extension agents, and others; and 7) Assist farmers to realize increased earnings by documenting four criteria among participating growers: a) reduced use of synthetic dewormers, b) increased animal productivity attributed to lower worm loads, c) reduced number of animals removed from organic marketing channels because of dewormer intervention and d) successful transition from conventional to organic farming due to increased confidence in coping with parasite issues. **PUBLICATIONS (not previously reported):** 2012/09 TO 2013/08 No publications reported this period.

[↑ Return to Index](#)