North Carolina (North Carolina Agricultural and Technical State University, North Carolina State University Combined) Annual Report - FY2021

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Contributing Organizations

North Carolina Agricultural and Technical State University
North Carolina State University

Executive Summary

Overview

This report reflects the accomplishments of Research and Extension programs from the College of Agriculture and Life Sciences (CALS) at North Carolina State University (NC State) and the College of Agriculture and Environmental Sciences (CAES) at North Carolina Agricultural and Technical State University (N.C. A&T). Our portfolios of cutting-edge, solution-driven research is extended to all North Carolinians through NC Cooperative Extension, to transform science into everyday solutions that improve lives and grow our state.

NC State Research & Extension: Despite disruptions caused by the COVID-19 pandemic that continued into 2021, Research and Extension faculty and staff in CALS stayed committed to providing solutions to the problems facing our state and nation. While navigating ever-changing COVID-19 protocols to protect the safety of the campus community and the public, CALS professionals continued working to transform science into everyday solutions that improve lives and grow our state. The North Carolina Agricultural Research Service (NCARS) and NC State Extension prioritized efforts aimed at solving the complex challenges facing food and agriculture.

Our extensive partnerships with business, industry and government generate a unique culture of interdisciplinary collaboration to address global challenges by merging creative, innovative ideas with purposeful action. The Plant Sciences Initiative is one such example. Through the initiative, CALS researchers and Extension professionals are collaborating with researchers from across NC State, industry, and every level of government bringing together the brightest minds in academia, government and industry to drive vital research and innovation. Initially envisioned by farmers, N.C. PSI utilizes an interdisciplinary approach to solving agricultural challenges, pairing experts from agriculture and life sciences with those from engineering, chemistry, and many other disciplines with the shared goal of addressing tomorrow's agricultural concerns today. In 2022, NC State cut the ribbon on the NC State University Plant Sciences Buildinge a cutting edge facility designed specifically to facilitate collaboration and creativity from issue identification through every step of research and development. NC State has also assembled the resources, partners and skilled personnel to shape growth in the food-animal industry. CALS and the College of Veterinary Medicine are partnering with industry leaders to bringing interdisciplinary sciences together to solve grand challenges and bring new ideas to market faster through a new North Carolina Food Animal Initiative. Through this initiative, NC State University is working to improve productivity, profitability and sustainability of industries in agriculture and the life sciences while helping North Carolina become the world leader in food-animal sciences.

Extension agents statewide serve as the conduit through which the needs of the community are communicated to the University. Local agents identify local challenges, present these opportunities to Extension specialists and faculty researchers who then conduct the research and find solutions. These specialists and researchers then train Extension agents in science-backed best practices to address the concerns. Through programs, training events, and hands on support, Extension agents deliver this essential information into the hands of the growers, industry, and members of the community. The cycle continues as new challenges arise, and NC State is poised to develop innovative solutions to meet the needs of our communities both here in N.C. and beyond.

N. C. A&T State University Research and Extension: Fiscal Year 2021 was another highly productive year for researchers within the College of Agriculture and Environmental Sciences (CAES) and for the College's outreach efforts through Cooperative Extension at N.C. A&T. The work summarized here presents accomplishments from research projects involving 24 research scientists. Additionally, our Extension professionals at the county and campus levels worked to provide educational programs through hands-on learning experiences and educational materials that help the audiences we serve.

Like previous year, CAES researchers and Extension staff faced several challenges due to the COVID-19 pandemic. However, all staff adapted well to the changing protocols and safety rules designed to make the campus community and public safe, and CAES is proud to report on a number of accomplishments in the four areas that comprise the College's target integrative research clusters. Research findings will help growers produce healthier, more robust crops, promote environmentally sound practices for pest control and control of livestock diseases, find new uses for swine manure, and much more.

Despite the ongoing impact of COVID-19, Cooperative Extension provided hands-on educational programs in 4-H STEM and leadership, financial resource management, health and nutrition, small farms, community gardens, sustainable agriculture, high tunnel production, industrial hemp, plasticulture, and agriculture and natural resource management across 41 counties in North Carolina. To ensure all participants had access to programs, some were modified to virtual formats such as Zoom, and Facebook Live. Programs such as the Plasticulture Rental/Cash Back program help N.C. A&T reach its mission of supporting limited-resource small farmers by saving farmers over $18,000 in equipment costs, contributing to the sustainability of their farms.

Critical Issue: Enhancing Food Safety, Nutrition and Health

NC STATE UNIVERSITY - Through research and extension efforts, NC State's College of Agriculture and Life Sciences not only developed novel approaches to producing healthier food and helped protect the safety of food across the entire supply chain but also encouraged consumption of healthy foods. As part of a multi-state research team to enhance food safety, researchers developed devices to deliver in-package sanitation of fresh packaged produce such as baby spinach, tomatoes, and mushrooms. Extension delivered training based on university-based research in produce safety (FSMA), acidified foods manufacturing, good manufacturing practices (GMP), hazard analysis and critical control points (HACCP), certified food protection manager (NC SafePlates), and home food preservation. NC State also led the formation of a multistate project team, FoodCoVNET, to fill a gap in research-based information that became visible as public health and regulatory officials scrambled to provide guidance for the food sector to address the emerging SARS-CoV-2 pathogen based on scarce data.

To enhance the supply of fermented dairy products and promote human health and nutrition, NC State researchers are developing and deploying technologies based on CRISPR, a family of DNA sequences found in bacteria and similar organisms. NC State's patents and expertise have been deployed commercially in fermented dairy products and the CRISPR genome editing technologies are also being deployed in crops, livestock, and even trees to breed a more sustainable, resilient food supply chain. To promote health and wellness, prevent chronic disease, and increase access to healthy foods, NC State Extension used a combination of research-based direct educational programs and policy, systems and environmental change efforts to help families and communities reduce barriers and implement behavioral changes. As a result of NC State Extension programs, 22,009 adults increased their fruit and vegetable consumption, 7,279 increased their physical activity, and 7,720 consumed less sodium in their diet. To reduce food insecurity and increase protein sources available at food banks, extension agents partnered with other nonprofits, food banks, hunter groups, and food processors to create a system for increasing the amount of venison donated to food banks. Extension also worked with farmers markets to establish donation stations for customers to donate produce for distribution to local food pantries.

N.C. A&T State University: Researchers are investigating environmentally friendly strategies for eliminating pests and insects from the stored cereal grain. They found that cinnamon, clove and thyme oils could be good alternatives to synthetic pesticides to control insects and mold in stored grains. Other research projects in this *integrative cluster area* included development of a novel frying medium to reduce the fat in fried chicken and fish, studies to increase the shelf life of food containing probiotics, and identification of dietary compounds, that can be obtained from parts of food plants that are typically discarded, like onion peel. Some of the compounds, including hemp and mushroom plant extracts, could be used as alternative antivirals and disinfectants for the control of novel SARS-Corona Virus-2 (SARS-CoV-2) on food and fomite surfaces.

Cooperative Extension focused its efforts on building skills and knowledge among limited-income audiences so they can eat healthier on a budget, make smart food and lifestyle choices, and increase their physical activity. The end goal was to develop adults and youth who have the skills and knowledge to stay healthy, live independently as they age, and avoid the chronic diseases that are prevalent in lower-income communities, such as heart disease and diabetes. Three programs were offered: 1) the Expanded Food and Nutrition Education Program (EFNEP); 2) the Try Healthy SNAP-Ed program; and 3) Lifelong Improvements through Fitness Together (LIFT). In 2021, Try Healthy SNAP-Ed reached 33,101 adults and youth throughout North Carolina, who learned to read food labels, eat healthier, and increase their daily physical exercise. EFNEP was offered in Martin, Durham, Vance, Warren, and Guilford counties, and reached 435 participants. Based on program evaluations, more than 90% of adult and youth participants improved their diets through EFNEP. LIFT focuses on building strength, flexibility, and improved balance in older adults. A total of 540 participants attended the program in nine counties. All participants reported improving their strength, agility, balance, and aerobic endurance.

Critical Issue: Enriching Youth, Family & Community Well-Being

NC STATE UNIVERSITY - NC State extension professionals found creative ways to enrich youth, family and community well-being. Extension provided resources to help parents and guardians promote healthy relationships, utilize positive parenting practices, and manage stress. Extension staff conducted counseling sessions to assist senior citizens with choosing Medicare Part D prescription drug plans. To support workforce development, NC State Extension provided education, guidance, and specialized training to entrepreneurs, program staff and interns, and minority owned business. Extension conducted outreach to lay critical groundwork to strengthen NC's economy while fostering healthy, engaged communities in which individuals from all backgrounds can thrive. Extension played a critical role in rolling out the North Carolina Department of Health and Human Services (NCHHS)'s plan to reach every farm in the state with COVID-19 response resources, including educational materials, masks, sanitizer, and vaccinations. NC State Extension participated in COVID-19 task forces across the state's farming governmental and nonprofit agencies to coordinate additional support for farmworkers.

To help youth develop life skills that will prepare them for future success, NC State Extension provided 4-H Youth Development programs that focused on civic engagement, healthy living, and STEM. In 2021 Extension offered a broad range of in-person and virtual 4-H educational programming. Activities included day camps and overnight camps; clubs; hands-on learning activities in the home, classroom, and community; online educational programs with video lessons and supplementary written materials; and interactive activity kits for children to enjoy during stay-at-home restrictions. 4-H used creative approaches to engage youth who were feeling the effects limited in-person learning and extracurricular activities by providing opportunities for hands-on activities. 4-H partnered with community organizations to provide pop-up STEM activities, created educational activity kits, camp-in-a-box kits, field days with small stations, and mini camps. 4-H also provided activities that focused on stress reduction and mindfulness to help with increased youth mental health issues arising from the ongoing pandemic.

N.C. A&T State University: Researchers studied the factors that influence aging in place (accession-1016492), including housing, residential environments, and physical activity levels. They found that physical activity levels in the elderly population were significantly associated with their residential environments and health conditions. Moreover, rural adults face additional challenges in the availability of transportation, medical care, affordable living, and educational programs. Other research projects in this *integrative cluster area* included community engagement, such as working with community members to improve their lifestyles and eating habits, and addressing their nutrition and overall well-being through trainings and workshops. Research also focused on working with both consumers and producers to enhance farm profitability by using value added products.

Cooperative Extension programs in this area aimed to provide opportunities, resources, leadership experiences, and hands-on education, especially for those who live in underserved areas of North Carolina. Youth learned about science, technology engineering and math (STEM) through the 4-H STEM Challenge, which focused on the history of humans in space. The 4-H Robotics program allowed youth to build and program their own robots, including drones. Financial stability often challenges lower-income families and Extension stepped up with programs on budgeting, savings, and debt reduction. The *You're Hired* program enabled youth to develop soft skills and leadership skills needed to succeed in the adult world. Community gardens supported by Extension brought people together in safe spaces to grow produce, improve their local environments, share their cultures, and become community leaders.

Critical Issue: Improving Plant and Animal Agricultural Systems

NC STATE UNIVERSITY - Agriculture and agribusiness – food, fiber, and forestry – account for one-sixth or $92.7 billion of the state's income. In the crops area, NC State researchers in the College of Agriculture and Life Sciences (CALS) conducted genetic research, developed new varieties, and developed new technologies and practices to increase production. Researchers applied cutting-edge genetic approaches that support more efficient development of new varieties with characteristics such as drought, disease and insect resistances allowing for reduced use of pesticides and fertilizers. NC State Extension agents and specialists provided a combination of virtual and limited size in-person field days and grower meetings to share the research and best management practices coming from the innovative work conducted by CALS scientists. Extension expanded its use of technology to deliver real time pest, disease, weather, and new technological and practice updates to growers during a time of COVID-19 restrictions and to keep growers informed about the latest developments. The use of social media, websites, educational videos, webinars, and online learning modules was expanded to reach remote audiences. Extension even started a podcast series, Crop Sense, featuring 20-minute segments with extension specialists that provide key information about crop production, profitability, and environmental sustainability. Horticulture agents provided additional programming to homeowners due to an increased interest in gardening stemming from families spending more time at home and food shortages due to supply chain disruptions.

In the area of animal agriculture, research and extension worked to support an industry that accounts for 70% of North Carolina's agricultural income and jobs. In response to public demand for antibiotic-free production, CALS researchers tested the effects of dietary interventions on the intestinal health and growth of nursery pigs without the use of antimicrobial growth promoters. Similarly, poultry

researchers worked on developing new ways to naturally enhance poultry gut bacteria to defend against antibiotic resistant germs. NC State researchers are also conducting research to determine the environmental and management factors that influence the longevity and fertility of honey bee queens, since queen problems are one of the major triggers of honey bee colony losses. NC State Extension specialists and agents delivered information on innovative products, technology, and best management practices developed through research conducted at NC State to producers using in-person and virtual workshops, certification programs, webinars, factsheets, and newsletters. Extension also led the creation of new disease and waste management plans, conducted on-site sludge surveys and equipment calibrations, and developed novel technologies to enhance animal health. Educational opportunities provided producers with knowledge of research-based best management practices spanning general animal husbandry, animal health, and disease management, waste management, poultry processing, and value-added marketing channels for calf sales including the use of electronic identification (EID) tags, co-mingled truckload lots, and quality assurance evaluations.

N.C. A&T State University: Research projects in this *integrative cluster area* focused on *plant/crop production* and *animal systems.* Researchers developed a local cultivation protocol involving micropropagation for producing ginger plants (accession-1013322). Micro propagated ginger showed great promise, demonstrating better resistance to disease, significantly more vigorous and healthier growth, higher yield per cultivar and an overall better consistency than seed-sprouted ginger, and could be a profitable niche crop for farmers. Researchers studied environmentally friendly ways to manage pests in crucifer and sweet potato. Results showed intercropping sweet potato (accession-1016488) with corn or pepper could be the best way to reduce pest damage and increase yields. Moreover, the sweet potato leaves have the potential to be used to prevent cell proliferation and migration in breast cancer. Other research included the development of cold and heat tolerant green leafy vegetables, best management practices for growing tuber borchii truffles, and evaluating season extension using plastic film layers. Our researchers also studied soil health and environmental benefits associated with CBD hemp production, and analyzed commodity pricing to assist in policy planning to help guide the direction of agricultural enterprise and production.

In research related to animal systems, our scientists studied the immune system's response to disease pathogens in ruminants to help determine ways to control and prevent disease. Other research related focused on improving the the physical, reproductive, and gut health of animals by identifying plant-based feed supplement, reducing greenhouse gas emissions by using plant-based feed, and using agricultural residue and crop extracts (such as onion peel) to produce antibiotic-free poultry. Research was combined with Extension outreach in several demonstration plots designed to help farmers transition to more sustainable and organic practices. The horticulture specialist tested 22 organic tomato cultivars and 12 cucumber cultivars. A pollinator demonstration project shows farmers and Extension agents how to use nature to control pests. Demonstration plots for both warm and cool season vegetables and educational programs helped small, limited-resource farmers adopt high tunnel agriculture techniques.

Other Extension programs focused on helping small and limited-resource farmers through education on production techniques such as high tunnels, the use of plasticulture, and new crops and commodities including hemp, ginger, and bees. A total of 140 growers attended workshops on hemp regulations and Extension published the comprehensive manual *All About Hemp*. N.C. A&T's Plasticulture Rental/Cash Back Program helped small farmers take advantage of longer growing seasons and increased yields without having to purchase expensive equipment. A Beginners Beekeeping School was launched in three counties with 138 participants. A total of 298 participants attended outreach events, such as the High Tunnel Winter Vegetable Field Day. Extension at N.C. A&T also launched its Small Farms Task Force, based on two years of needs assessments and listening sessions across the state. The task force began an initiative called *Small Farm Leadership 360*, which includes educational modules on production agriculture, marketing, farm cooperatives, and agriculture best practices. The first module was conducted in February 2022 and three more are planned for 2022.

Critical Issue: Protecting Environmental and Natural Resources

NC STATE UNIVERSITY - NC State College of Agriculture and Life Sciences developed and promoted research-based natural resource stewardship, and climate-smart agricultural and forestry best management practices to sustain the quality and diversity of North Carolina's natural resources, conserve and protect the environment, boost sustainable energy, and mitigate climate change. Researchers and extension specialists partnered with the NC State Climate Office to develop a tool to provide key data to pesticide applicators so they can carefully time their applications and minimize pesticide drift. In addition, pesticide training programs helped applicators meet requirements to maintain their licenses. To minimize environmental harm from animal agricultural operations, extension agents and specialists provided thousands of animal waste operators with training and education enabling them to maintain required permits, implement best management practices, and avoid fines. In addition, researchers studied the effect of poultry litter application on crop yields and quality. NC State research and extension efforts also focused on protecting the quality of water supplies within the state. CALS researchers analyzed geospatial data to evaluate septic system vulnerabilities. The data is being used in extension activities to inform the public in coastal communities about septic systems, water quality, and human health. Extension specialists also helped protect water

quality by installing sites for demonstrating best management practices, leading streambank repair projects, monitoring water contamination, developing stormwater plans, and educating thousands of wastewater operators, erosion control professionals, environmental health specialists, septic system installers, engineers, soil scientists and others.

N. C. A&T State University: Research in this *integrative cluster area* focused on water quality and clean energy. Researchers are studying engineering techniques to improve on-farm water quality. Another group of researchers are studying potential ways to convert carbon content waste from swine manure, oakwood, and miscanthus into advanced multifunctional carbon nanomaterial.

Extension work aimed at protecting environmental and natural resources focused on disseminating information to help small farmers protect their soil, water, and natural environment, manage their natural resources, reduce their environmental footprints, and sustain their farms while dealing with the challenges of climate change. The agriculture and natural resources (ANR) team distributed natural resource testing kits and collected baseline data from the Alley-Cover Cropping Project on the N.C. A&T University Farm. Extension at A&T brought together about 100 farmers and community leaders from across the state in October 2021 for the Grassroots Leadership Conference, which focused on forest management resources, conservation practices, and land ownership issues. Extension also collaborated with the North Carolina State Climate Office to teach, train, and educate small-scale, limited resource, and minority farmers on how to modify farming practices to cope with a changing climate. Kit bags that included comprehensive soil testing tools were supplied to ANR agents and Extension technicians to allow them to rapidly diagnose issues that farmers and landowners face with their soil, water, farm, and land environments.

Merit and Scientific Peer Review Processes

Updates

NC STATE UNIVERSITY - None

N.C. A&T State University: None

Stakeholder Input

Actions to seek stakeholder input that encouraged their participation with a brief explanation

NC STATE UNIVERSITY - None

N.C. A&T State University: None

Methods to identify individuals and groups and brief explanation

NC STATE UNIVERSITY - None

N.C. A&T State University: None

Methods for collecting stakeholder input and brief explanation

NC STATE UNIVERSITY - The NC State College of Agriculture and Life Sciences (CALS) Compass 2030 strategic planning process, which kicked off in spring 2021, is well underway and making great progress towards the creation of our new strategic plan that will chart the course for CALS through the year 2030. We use our strategic plan to guide and direct the college as we pursue exceptional learning and working spaces, innovative research, deliver exceptional teaching, and determine the most impactful ways to connect with the community via Extension. We have specifically designed this process to be stakeholder-driven to ensure the plan is a reflection of everyone within, or touched by, the CALS community. Over the past year the planning team, which includes faculty and staff representation from across the college, has engaged internal and external stakeholders in the strategic planning process through a series of surveys, interviews, small-group meetings, focus groups, and larger listening sessions. These avenues provided for our faculty, staff, and student groups; university and college leaders, including department heads and various other unit leaders; and external stakeholders across the state to have an opportunity to make their voices heard. NC State Extension is also creating a cascaded strategic planning process that is underway drawing from key themes identified in the CALS process and further exploring the Extension related themes with stakeholder groups through interviews, focus groups, listening sessions, and surveys.

N.C. A&T State University: In spring 2021, we asked an external firm to conduct a statewide needs assessment to determine how to best meet the needs of the state's citizens in the areas of youth development, agricultural and natural resources, community and rural development, and family and consumer sciences. The external firm conducted focus groups, virtual interviews, mailed surveys, reviewed census data, and programmatic documents. The firm held 32 regional and three targeted focus groups and used a stakeholder list provided by Cooperative Extension. More than 630 individuals responded to the survey. This group included farmers, educators, community leaders, and parents of program participants. This process helped N.C. A&T in preparation for developing the renewed strategic direction based upon stated needs of ctizens.

A statement of how the input will be considered and brief explanation of what you learned from your stakeholders

NC STATE UNIVERSITY - Stakeholder input was used to set research agendas and extension program priorities by identifying emerging issues and relevant community needs. In 2021, stakeholder input surrounding the needs resulting from the COVID-19 pandemic guided operational, research and programmatic functioning. On the operational side, stakeholder input influenced how and where programs were delivered and the method of program delivery including the use of virtual and reduced size group programs. Some research efforts shifted to study COVID-19, farmworker safety, food safety, vaccinations, and other related topics based on stakeholder needs. Extension programming also shifted to address stakeholder identified needs including food insecurity, mask and vaccination distribution efforts, school closures, wellness and stress caused by isolation, financial hardships, food preparation, and other community needs.

N.C. A&T State University: Stakeholder input was used to set program priorities, identify emerging issues, redirect extension programs, redirect research priorities, set staffing priorities and direct budget priorities. Because research and extension activities are directed toward the development and implementation of new knowledge and technology, faculty members are constantly relating industry and consumer needs to the discovery process. Stakeholder input is also used in determining research and extension directions and gaining program support and advocacy for research and extension initiatives. For example, the commodity association boards provide information on high-priority research areas to be used in requests for proposals, and boards then decide which proposals to fund. This type of stakeholder input has a direct effect on research activities and subsequent extension programming. Our environmental scanning process identifies key issues of concern and needs of the community and allows us to translate these needs into science-based programs and services.

Ninety percent of the participants were satisfied with the programs they'd participated in over the past three years, found them useful, and overwhelmingly recommends Cooperative Extension to their friends and colleagues. Recommendations from the survey participants helped us develop our commitments to how we will do our work and interact with those who use our programs and services. Based on the results, N.C. A&T intends to (1) continue to focus on programming in areas that serve our primary clientele, small farmers and limited-resource population, (2) continue to work with and use the resources of the entire cooperative extension and land-grant university system to identify best practices and implement programs and activities when they ate a good fit for our audiences, (3) work with N.C. State University and all state-and-county-based partners to ensure that all of the states' citizens are receiving quality programs and treated with respect and dignity, (4) intensify our collaboration and partnership with N.C. State University and ensure that all campus and field-based staff are aware of all assets, resources, and opportunities, and (5) implement strategies that are designed to meet program needs. The recommendations from participants and commitments helped form the foundation for the strategies that will guide us through 2023 as we decide how to allocate our time, resources, and efforts. These strategies will drive our strategic plan, "Mission Possible: Continuing to Inspire North Carolinians to Improve Their Lives".

Highlighted Results by Project or Program

Critical Issue

Enhancing Food Safety, Nutrition and Health

Characterization of plant extracts as a potential surface disinfectant

Project Director

Leonard Williams

Organization

North Carolina Agricultural and Technical State University

Accession Number

1023620

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Conventional intervention methods used to inactivate viruses (ie., alcohol, household bleach, and other formulations) have shown to be ineffective on select food contact and other surfaces likely to carry infections (fomite surfaces). Therefore, alternative antiviral agents such as, phytochemicals have received attention as potential norovirus inhibitors due to their relatively low toxicity and lack of side effects, which allows them to be prepared as food-safe formulations. This project aims to evaluate the potential of hemp and mushroom plant extracts as an alternative antiviral and disinfectant replacement for the control of novel SARS-Corona Virus-2 (SARS-CoV-2) on food contact and fomite surfaces. Conventional intervention methods used to inactivate viruses (ie., alcohol, household bleach, and other formulations) have shown to be ineffective on select food contact and other surfaces likely to carry infections (fomite surfaces). Therefore, alternative antiviral agents such as, phytochemicals have received attention as potential norovirus inhibitors due to their relatively low toxicity and lack of side effects, which allows them to be prepared as food-safe formulations. This project aims to evaluate the potential of hemp and mushroom plant extracts as an alternative antiviral and disinfectant replacement for the control of novel SARS-Corona Virus-2 (SARS-CoV-2) on food contact and fomite surfaces.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

In the first year of the project term, the goal of extraction of phyto-constituents from raw plant material and their products was completed. For Hemp, 48 extracts were prepared in total using different plant material (seeds, leafy biomass, distillate, and oil). The extracts were prepared in triplicates using various solvents and techniques such as ultra-sonication, centrifugal rota evaporation and freeze drying.

Briefly describe how your target audience benefited from your project's activities.

The interdisciplinary and extension activities of the project involved surveys conducted on the use of conventional and natural products-based disinfectants use. A zoom workshop was conducted on education of school students on practical approaches to combat COVID infection and spread. Dissemination of project related scientific information was carried out through publication of 2 review articles in peer reviewed journals.

Briefly describe how the broader public benefited from your project's activities.

A better understanding key bioactive compounds that can be used as an alternative disinfectant compared to conventional commercial disinfectants to inhibit the growth of novel SARS-CoV-2 on different surfaces (food or fomites) is being developed. This solution will enable stakeholders to use a safe and environmentally friendly disinfectant to sanitize food contact surfaces.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

The pandemic situation has affected the logistics of obtaining the consumables for experiments in a timely fashion. Despite the challenges posed by with phased return of staff to workplace, the team has successfully completed objective one of the proposed research work. This work has supported the training of research scholars (Research Associate and 2 Graduate Assistants) during this fiscal year. Training has included method development for extraction of bioactive compounds, machine learning and programming and scientific writing. Currently, the initial objectives of the project have been accomplished. After the evaluation of the bioactivities of the extracts, plans for further continuing research based on the outcomes of this screening will be designed to understand the anti-viral properties and mechanisms for inactivation of SARS-CoV-2.

Deepti Salvi
Organization
North Carolina State University
Accession Number
1023653

In-package sanitation of fresh-produce

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

(1) Characterize physical, chemical, and biological properties of raw and processed foods, by-products, and packaging materials. (2) Develop advanced and sustainable processing and packaging technologies to transform raw materials into safe, high quality, health-promoting, and value-added foods. (3) Develop mechanistic and data-driven mathematical models to enhance understanding and optimization of processes and products that will ensure sustainable and agile food manufacturing for safe, high quality, and health-promoting foods.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

We have collaborated with universities in different states in the US on food processing technologies and food safety under the second goal of the project. Specifically, we: 1. Developed conformable plasma electrodes for the in-package sanitation of fresh-produce such as baby spinach, tomatoes, and mushrooms (collaboration with the Department of Mechanical and Aerospace Engineering, Rutgers University). 2. Applied plasma-activated nutrition solution for enhancing the growth and yield of hydroponic basils (collaboration with the Department of Food Science, Rutgers University). 3. Developed plasma-activated mist as a novel sanitation strategy for fresh produce (collaboration with the Department of Food Science, Rutgers University). 4. Developed DNA-based surrogates and machine learning strategies for the validation of sanitation efficacy of cold atmospheric pressure plasma and plasma-activated water (collaboration with the Department of Food Science and Technology, University of California, Davis). Though not initially opted, we also helped in planning and participated in one credit multi-institutional seminar course (20 enrolled students in Spring 2021).

Briefly describe how your target audience benefited from your project's activities.

Our results were presented at local and international conferences or seminars and were also submitted to peer-reviewed journals for publication. The results have significant impacts on both research knowledge and the food industry to improve food safety, quality, and nutrition, and will benefit audiences including college students, researchers in food safety and processing, industry stakeholders, and the general public. Specific products are:

Conference abstracts

1. Wang, Q., Pal, R., Trosan, D., McLaughlin, S., Mazzeo, A., Stapelmann, K., Salvi, D. (2022). Flexible cold plasma electrodes for in-package sanitation: Evaluation of sanitation efficacy and quality changes in mushrooms. Institute of Food Technologists (IFT), virtual conference.

2. Rivero, W., Wang, Q., Salvi, D. (2021). Comparison of cold atmospheric pressure plasma (CAPP) and plasma-activated mist (PAM) for inactivation of *E. coli* DH5α, *Listeria innocua*, and *Salmonella* Typhimurium. *Institute of Food Technologists (IFT), virtual conference*.

3. Rivero, W., Wang, Q., Salvi, D. (2021). Development of Plasma-based Decontamination Treatment for Hydroponic Nutrient Solution. *International Association for Food Protection conference (IAFP), virtual conference*.

4. Trosan, D., Wang, Q., Pal, R., Mazzeo, A., Salvi, D., Stapelmann, K. (2021). High-Quality Manufacturing of Packaged Fresh Produce with Conformable In-Package Cold Atmospheric Plasma. *74th Annual Gaseous Electronics Conference, virtual conference*.

5. Pal, R., Wang, Q., Salvi, D., Mazzeo, A. (2021). Paper-based Cold Plasma-generating Electrodes for the Inactivation of Food-pathogens. *European Materials Research Society, virtual conference*.

Peer reviewed articles

1. Wang, Q., Pal, R. K., Yen, H. W., Naik, S. P., Orzeszko, M. K., Mazzeo, A., & Salvi, D. (2022). Cold plasma from flexible and conformable paper-based electrodes for fresh produce sanitation: Evaluation of microbial inactivation and quality changes. *Food Control*, 108915.

2. Wang, Q., Cui, H., Salvi, D., & Nitin, N. (Under review). DNA-based Surrogates for Validation of the Microbial Inactivation Process for using Cold Atmospheric Pressure Plasma (CAPP) and Plasma-activated Water (PAW) processing. *Journal of Food Engineering*.

3. Rivero, W., Wang, Q., & Salvi, D. (Under review). Effect of Plasma-activated Water on Microbiological and Quality Characteristics of Alfalfa Sprouts, Broccoli Sprouts, and Clover Sprouts. *Innovative Food Science & Emerging Technologies*.

4. Date M., Rivero W. C., Tan J., Specca D., Simon J., Salvi, D. and M.V. Karwe (Under review) Effect of plasma-activated nutrient solution (PANS) on sweet basil (O. basilicum L.) grown using an ebb and flow hydroponic system. *Scientia Horticulturae*.

Magazine Article

1. Salvi, D. and M.V. Karwe (2021) Sustainable and safer indoor farming of produce using new technologies: challenges and opportunities. The International Union of Food Science and Technology (IUFoST), Scientific Information Bulletin (SIB). http://www.iufost.org/news/urban-food-production-new-sib.

Invited talks

1. Wang, Q. Conformable and Flexible Surface Dielectric Barrier Discharge for Fresh Produce Sanitation. Multi-Institutional Food Engineering Seminar Series Organized as part of USDA Multistate Committee NC1023. Virtual Presentation. March 4th, 2022.

2. Salvi D. Research updates on cold plasma technology. Seminar for the Department of Food Science & Technology, University of Georgia. Virtual presentation. November 4th, 2021.

3. Salvi D. Research updates on cold plasma technology. Seminar for the Department of Food Science & Technology, The Ohio State University. Virtual presentation. Oct 5th, 2021.

4. Salvi D. Applications of Cold Atmospheric Pressure Plasma in Agriculture. (2022). Seminar for the BASF Corporation. Virtual presentation. April 8th, 2021.

5. Salvi D. (2021) Food Processing. Invited Speaker, RTP180 to present a TED-style talk at RTP 180: Food Science at Frontier RTP. September 16, 2021 pbs.org/video/dr-deepti-salvi-nc-state-food-science-8pzbbl/

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Briefly describe how the broader public benefited from your project's activities.

Consumers expect the US food industry to develop and deliver safe, high-quality, nutritious, and healthy food products while also addressing several emerging sustainability issues such as resource consumption, food loss and waste, food waste management, and food safety. With these demands have emerged a need for food engineers to develop and deliver novel solutions to address these competing challenges. However, many key technical hurdles need to be overcome to meet these goals. These technical hurdles include: (a) limited characterization of physical, chemical, and biological properties of foods that influence their quality and susceptibility to spoilage and contamination; (b) the need for optimization of existing technologies or discovery and translation of new sustainable food processing and packaging technologies that can deliver safe, nutritious, healthy, and high-quality foods; (c) the need for the development of novel methods to collect and analyze big data and its utilization in product and process development; (d) development and refinement of mathematical models that can enhance the understanding of fundamental dynamics within food processing operations to enable accurate prediction of safety and quality attributes of foods; and (e) training of the next generation of food industry professionals that are equipped with science and engineering tools to address these issues facing the food industry. To solve these technical hurdles, there is a critical need for interdisciplinary efforts and collaboration among food engineers, food scientists, and food industry professionals across the nation. Only with continued dialog and collaboration will truly transformative solutions be discovered to overcome the challenges facing the US food industry. Due to the collaborative nature of NC-1023 and the widespread participation from universities across the country, this multistate project is well-positioned to tackle these challenges to benefit the public and the nation.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

A postdoctoral researcher, one Ph.D. student and a master student were involved in the projects.

The following goals are expected to be accomplished: 1. Develop and optimize metallized paper-based conformable plasma electrodes of different types; apply the electrodes for the sanitation of different fresh produce. 2. Understanding the role of reactive species in the growth of sweet basil. 3. Develop protein-based surrogates for validation of the sanitation efficacy of the cold plasma and plasma-activated water. 4. Continue participating in the multi-institute seminar course.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

Consumers expect the US food industry to develop sustainable, safe, high-quality nutritious food products. NC State researchers have begun to tackle these challenges by collaborating with other universities in a multistate research project using innovative technologies that are more sustainable and chemical residue free. The researchers are using cold plasma, the fourth state of matter, which can be generated by passing electricity through air, for various applications. Novel cold plasma devices were developed to deliver in-package sanitation of fresh produce such as baby spinach, tomatoes, and mushrooms, and plasma-activated mist was used as a novel strategy for fresh produce sanitation. Protein-based surrogates and machine learning strategies were used to analyze the efficiency of plasma-based sanitation approaches. In addition, researchers demonstrated the use of plasma-treated solution to enhance the growth and yield of hydroponic basil. Cold plasma applications in food and agriculture can improve food safety, enhance plant growth, and reduce water, energy, and space usage. With this new technology, rather than putting produce in a plastic bag at the grocery store, it could come pre-treated with plasma to prevent the growth of harmful bacteria, then packaged in a sealed, recyclable container. Results have been presented at local and international conferences and seminars and submitted to peer-reviewed journals. These results lay a critical groundwork for enhancing food safety, quality, and nutrition while addressing the issues of food waste and environmentally harmful packaging. This demonstrates how NC State is growing solutions, protecting the environment, and serving all North Carolinians.

Food Safety

Project Director

Meredith Weinstein

Organization

North Carolina State University

Accession Number

Enhanced Food Safety Through Information, Resources and Programming to Prevent Food Safety Hazards

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Despite food safety communication efforts by many sectors, foodborne illness remains a significant health issue in North Carolina and across the U.S. The Center for Disease Control (CDC) estimates that as many as 48 million cases of foodborne illness occur annually, leaving 128,000 people hospitalized and causing 3,000 deaths. The majority of foodborne illness is caused by 31 major identified pathogens, including norovirus, salmonella, and listeria. Regardless of cause, foodborne illness costs society an estimated $152 billion annually.

Most estimates suggest that 70% of foodborne illnesses are acquired outside of the home. There are a multitude of opportunities for foodborne illnesses to be introduced into the food system including poor sanitation during production and processing; unsafe storage and handling of the raw products; improper washing and cleaning of equipment; undercooking, lack of proper chilling, and cross-contamination. Foodborne illness is nearly 100% preventable if safe food handling practices are applied from the time food is received until it is served, and if an outbreak occurs, the National Restaurant Association estimates it could cost an establishment $75,000 in addition to posing a threat to public health.

Home food preservation continues to be an area of interest for North Carolinians wanting to take advantage of the abundance of available foods from home gardens or local markets. The local food movement and current economic situation have led to a resurgence in home food preservation as a viable alternative to contemporary food purchase. When preserving, it is essential to employ evidencable, research-tested strategies and methods to ensure the safety of products.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

NC State Extension utilized various methods to enhance food safety throughout the supply chain through producer and consumer-based information, resources and programming aimed at preventing food safety hazards.

- NC State Extension Specialists disseminated new food safety information and best practices through the publication of 103 Extension factsheets and publications to educate Extension Agents, producers, members of industry and the public.

- NC State Extension Specialists maintained 5 food safety-related educational websites with a reach of 76,858 and made 1027 educational social media posts with a reach of 745,454.

- NC State Extension Specialists produced 60 on-demand educational videos on food safety-related topics that were viewed 506,278 times.

- 4,606 individuals attended food safety training provided by Extension Agents and an additional 3,683 individuals attended training provided by Extension Specialists.

- Food safety technical assistance was provided to 452 people by Extension Agents, and Specialists provided services to an additional 840 clients.

As required by U.S. food and drug regulations, the formulation and process to make acidified food are reviewed for product safety and to ensure critical limits of ingredients and thermal processing are met. **The Entrepreneur Initiative for Food (EI4F)** program ensures individuals and firms transform agriculture commodities into safe, nutritious, value-added food and beverage products by classifying foods according to FDA standards and providing research-based processing recommendations. In 2021, 855 requests for product testing services and 542 nutritional label requests were received. EI4F provided 696 processing recommendation letters and certified 308 individuals for the manufacture of acidified foods via the Acidified Foods Manufacturing School online course. **Good manufacturing practices (GMP)** is a system that consists of

processes, procedures and documentation that ensure manufactured products, such as food, are consistently produced and controlled according to set quality standards. An Extension Specialist worked with a small company producing a locally manufactured food product in meeting GMP requirements for sanitation and improved product quality. Through consultation and technical assistance with equipment disassembly and sanitation procedures, the Extension Specialist pinpointed the cause of spoilage contamination, preventing further loss of finished product and ensuring a safe food product.**NC State Extension's extensive partnerships with agriculture, business, and industry resulted in the development of safe new food products.**

Processing fresh produce into fresh-cut products increases the risk of bacterial growth and contamination by breaking the natural exterior barrier of the produce. An Extension Specialist worked with the owners of a food hub to expand their business into fresh-cut processing. The Specialist assisted with achieving compliance with third-party audit requirements and state/federal food safety requirements**. NC State Extension's trusted research-based technical assistance increased processor knowledge of food handling, processing, cross-contamination, and hygiene-resource limitations that can occur in food production.**

Hazard analysis and critical control point (HACCP) and food safety go hand in hand. The HACCP system uses a systematic, science-based approach to identifying specific hazards and controlling critical points in food handling to prevent food safety problems and reduce the reliance on end-product inspection and testing. The Retail Hazard Analysis and Critical Control Point (HACCP) course for regulators and restaurant operators was transitioned to an online format in late 2020 in response to in-person meeting restrictions caused by the COVID-19 pandemic. Through online training and collaboration with local Extension agents, 306 regulators and operators from across the US received 3,672 contact hours of instruction surrounding retail hazard analysis and critical control point food processing safety standards. Also in 2021, Extension provided 14 seafood industry personnel with training in **Seafood HACCP** and assisted in writing or reviewing 10 HACCP plans for 5 companies. Technical assistance and advice regarding seafood science inquiries were provided to 11 individuals/companies through phone calls and meetings, and 3 quality analysis product tests were conducted for 3 companies. **The HACCP training and assistance with plan writing, science-based technical advising, and quality analysis product tests were just part of how NC State Extension increased producers' knowledge of BMPs that reduced the likelihood of foodborne illness.**

The **NC Safe Plates** program team develops practical food safety training and educational materials for retail and consumers to impact attitudes, norms, and behaviors around food safety. In 2021, 4 new Safe Plates programs were developed: Safe Plates for Food Managers (online), and Safe Plates at Home: General, Holiday Gatherings, and Disaster Preparedness and Recovery. In addition, 100 new resources, including informational sheets and social media images, were developed. Through collaboration with local Extension Agents, a total of 2,712 hours of NC Safe Plates training was delivered, and 226 participants achieved Safe Plates for Food Managers Certification. Extension Specialists provided technical assistance in 800 food safety cases. The NC Safe Plates Food Safety Information Center created 1,027 posts and 55 videos on Instagram, Facebook, TikTok, and Twitter, which reached a total of 745,454 individuals. Utilizing a novel, yet popular approach to information sharing, 506,260 individuals were reached using 52 videos on TikTok and Instagram's Reels function. These novel communication methods reached consumers far beyond what we would be able to accommodate in in-person classes and training. **NC State Extension reduced food-related illness outbreaks through research-based education and consumer engagement.**

To enhance food safety, Extension helped individuals and families increase their knowledge of food safety through in-person and online workshops, educational social media content, articles and factsheets, instructional videos, and educational TV programming. Extension in Hyde, Gaston, Forsyth, Beaufort, Haywood, Nash, and Wilkes Counties helped over 10,393 individuals learn best practices for safe **home food preservation** via in-person and online workshops, articles, and instructional videos. Topics included canning, pickling, freezing, foodborne pathogen science, safe thawing, home-canned food storage, dehydration, and fermentation. Although most of the consumers who benefitted from these efforts were NC residents, Extension Agents reported engagement with consumers around the globe, including residents of England, Germany, and Canada. Extension in Dare County, via cable and video on demand, reached over 5,000 viewers with education programs spanning food safety, home food preservation, healthy recipes, and more. In Beaufort County, over 8,894 people received accurate information on the importance of proper canning methods as a result of articles and instructional videos on home food preservation of pickles, jams and jellies, and green beans; 42 consumer food preservation questions were answered by phone and email during the canning season, and seventeen dial gauge pressure canners were tested by a certified gauge during the summer at the Cooperative Extension Office. Two dial gauge pressure canners were inaccurate. Consumers followed up and replaced defective gauges to ensure safe food preservation products for their families. **NC State Extension's extensive statewide network of county-based agents provided families with trusted research-based knowledge to prevent foodborne illness.**

Briefly describe how your target audience benefited from your project's activities.

Small farms that sell through direct market channels and to the local food hub are typically not GAP audited or subject to the requirements of the FSMA produce safety rule. Nonetheless, all farms need to be knowledgeable about how to manage produce safety risks and how to implement postharvest practices that will improve the safety of their produce. A local food hub no longer required growers to be GAP audited but they still wanted all growers to have basic produce safety training. To address this training need, a 2-hour **Quality Produce from Harvest to Market** workshop was held at the TRACTOR food hub facility. Nine growers and 1 food hub staff member attended the training. As a result of the training, all evaluation respondents indicated that they improved their knowledge in at least one area. **Extension Area Specialized Agents helped educate growers about the Food Safety Modernization Act (FSMA), the Produce Safety Rule, and the Preventive Controls Rule for Human Food.**

Selling home prepared food such as jams, jellies, cakes, and other baked goods has become popular. However, selling home-prepared food comes with risks. Community & Rural Development and Family & Consumer Sciences Agents in Nash, Edgecombe, and Harnett counties offered a program, ***NC Homemade,*** to bring awareness to food safety and the risk of selling food products from home. NC Homemade was adapted from the University of Florida's Homemade Entrepreneur program and developed with the assistance of UF/IFAS Extension. Following the first year of the program, one participant reported that they already passed inspection with their home kitchen and started their new business venture, two participants branched out their products to offer a broader selection at the farmers market, and all participants reported increased knowledge in food safety, business marketing, budgeting, and NC food laws. **NC State Extension enhanced food safety through programming aimed at preventing food safety hazards during the food manufacturing process.**

To reduce foodborne illness outbreaks, FDA Food Code requires a Certified Food Protection Manager to be onsite during hours of operation at food service establishments. To address the growing need for food safety training opportunities, the Safe Plates team developed an online, self-guided, **Safe Plates for Food Managers** program. Hyde County was 1 of 5 counties to participate in the pilot of the Safe Plates for Food Managers online program. Participants independently completed the modules and contacted the Family and Consumer Sciences Agent with questions along the way. All 8 participants passed the exam on their first attempt. One of these individuals took the course in preparation to open her deli in a town that previously had no restaurant options, a dream for her that is now a reality. Bladen County Cooperative Extension also volunteered to pilot the new virtual Safe Plates for Food Managers program. As a result of participating in the Safe Plates for Food Manager's pilot, 2 foodservice employees in Bladen County have successfully passed the Safe Plates for Food Managers examination. For one participant the impact of being able to complete this course and take the exam doesn't end with just the passing score, it also means that she is now able to move forward with opening her restaurant, something she has been working towards since before the pandemic. **As a leader in experiential education, NC State's Safe Plates program equipped food production managers and handlers to effectively transfer best management practices into practical application.**

Food-insecure families took charge of their home food safety practices after participating in the **Expanded Food and Nutrition Education Program (EFNEP)**. Educators used Zoom, Facebook Live, Google sites, and phone communications to engage with 3,177 low-income families and youth statewide. Ninety-one percent of EFNEP graduates improved their food safety skills. Participants were given a meat thermometer and shown proper use In McDowell County's EFNEP program. Ninety-four percent of EFNEP participants showed improvement in the food safety practice of using a thermometer, enabling these families to practice safe food preparation in the home.

The National Center for Home Food Preservation revealed that a large percentage of home food processors are using outdated and unreliable **home food preservation practices** that put them at risk for foodborne illness. One area of home food preservation that experienced a surge in interest in fermentation. Family & Consumer Science (FCS) Extension Agents from Haywood, Madison, Yancey, and Buncombe Counties collaborated to offer a virtual home food preservation series entitled "Ferment On." Agents offered a series of 5 virtual classes on fermenting kimchi, kombucha, pickles, sauerkraut and yogurt. An average of 45 participants attended each of the 5 classes and were provided with virtual demonstrations, Q&A sessions, fact sheets, recipes, links to reliable resources, and video recordings. Participants gained reliable information on fermenting as a means of food preservation. A group of 6 Extension Agents partnered to educate community members in a 7-county area about safe home food preservation of local foods. Six virtual workshops covering an introduction to home food preservation, pressure canning, boiling water canning, freezing, fermentation, and sweet spreads were provided to a total of 509 people. Participants commented that "I appreciated the expertise and the genuine concern that everyone learned safe methods of preserving" and "I am just learning the basics. I thought I had canned correctly before using instructions from the internet, but I did it completely wrong. I sincerely appreciate Extension providing this information!"

FCS Agents in Nash/Edgecombe, Martin, and Bertie counties noticed an increase in misinformation about food preservation on the internet and videos showing improper food preservation techniques. In response, the agents hosted a virtual home food preservation program with 10 food preservation classes. Over 450 participants learned about water bath and pressure canning and fermentation. Several participants shared that they had done some home food preservation in the past but openly admit it was not the proper way and they were very thankful we offered these classes. Cooperative Extension's Gaston

County Center conducted 8 online food preservation workshops for 205 participants. As a result of the training, 75% of participants plan to purchase local foods for home food preservation within the next 6 months, and 75% learned new food safety techniques and plan to use skills for home food preservation within the next 6 months. Gaston County found that the online workshops have been a great way to attract new Extension audiences to participate in other Extension programs such as local food workshops. By conducting in-person classes in Beaufort County with demonstration and hands-on education, over 65 individuals learned about proper techniques to prevent foodborne illness by preserving pickles, jams and jellies, and low-acid vegetables and meats. Ninety-eight percent of participants gained knowledge of proper canning methods and techniques. Participants left knowing Extension shared research-based information to improve their knowledge and practice in home food preservation and with the skills to preserve food that will be safe to consume. **NC State Extension improved consumer health and reduced food-related illness by increasing consumer knowledge of safe food preparation and preservation practices. NC State Extension is a reliable educational resource to teach food safety to consumers.**

Briefly describe how the broader public benefited from your project's activities.

The global SARS-CoV-2/COVID-19 pandemic has caused unparalleled millions of illnesses and hundreds of thousands of deaths worldwide. This pandemic has had a direct impact on the US food supply, forcing the food sector and regulatory communities to address this emerging pathogen based on scarce data. Public health and regulatory officials scrambled to provide guidance for the food sector early in the outbreak. A multistate project team, **FoodCoVNET**, led by NC State Extension Specialists stepped in to fill this gap.

A review and cataloging of the existing and expanding literature was conducted and utilized to provide ongoing, science-based technical support to the food sector. Through this project SARS-CoV-2/COVID-19 concerns are being addressed by evaluating practices and confirming efficacy through laboratory research on virus persistence, inactivation, and transfer. This knowledge is being translated into a variety of forms to aid in future decisions, and the outputs are being housed on a public website for widespread distribution. FoodCoVNET has a foundation of stakeholder engagement, utilizing an iterative approach to gather information from food sector constituents and industry leaders to ensure that data gaps are identified and filled.

FoodCoVNET has developed peer-reviewed resources providing best practices for preparing for COVID-19 and managing risk for individuals at home and for food environments based on guidance and best practices as outlined by the Centers for Disease Control and Prevention (CDC), the Environmental Protection Agency (EPA), the United States Department of Agriculture (USDA), the Food and Drug Administration (FDA), the World Health Organization (WHO), and the best available science. The resources, which include infosheets and social media images in multiple languages, have been developed for 3 distinct audiences: household and community management of the virus; retail and food establishments; and farms, gardens, and produce. The FoodCoVNET project team has also coordinated a webinar series and offers the FoodCoVNET University for Businesses training series focused on providing the necessary knowledge and information needed to manage COVID-19 within businesses as restrictions are relaxed. The 5 courses in this series provide a consistent approach based on state and national guidelines and are designed to incorporate the best available science in social and physical distancing; employee health; and cleaning, sanitizing, and disinfection. As a leader in experiential education, Extension presents these courses considering adult education and behavior theories, with each of these short training sessions being designed to be less than 30 minutes long and delivered online in an engaging, interactive format.

Research has found that neither food nor food packaging are considered significant ways of spreading or causing the COVID-19 virus. However, it is always important to follow good hygiene practices when handling or preparing food for yourself and others to prevent foodborne illness. **Providing science-based strategies and practices to reduce the public health and economic impacts of COVID-19 on the food sector and all North Carolinians is how we are growing a healthy, vibrant North Carolina.**

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

The following professional development workshops were provided by Extension Specialists for Extension Agents in 2021 to facilitate the use and transfer of new research-based knowledge:

- Assessing Risks to Promote a “Food Safety Culture” in NC Produce

- Disaster Preparedness and Recovery Training
- Home Food Preservation 101
- Irrigation water and produce safety
- Produce Handling Facility Tour and Training
- Produce Safety Alliance Training
- Safe Plates for Food Managers
- Who Regulates Our Food?

Websites:

FoodCoVNET

Retail & Consumer Food Safety

Home Food Preservation

Food Safety for Processors

Fresh Produce Safety

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

Despite food safety communication efforts by many sectors, foodborne illness remains a significant health issue in North Carolina and across the U.S. NC State Extension utilized various methods to enhance food safety throughout the supply chain through producer and consumer-based information, resources and programming aimed at preventing food safety hazards. NC State Extension provided technical assistance to food businesses to ensure the safe development and production, packaging, and distribution of food products for human consumption. Extension also provided training to food service employees and managers to ensure safe handling of food at retail establishments and prevent outbreaks of foodborne illness. Extension's efforts also reduced the incidence of foodborne illness in the home through the transfer of research-informed best practices to consumers on home food preparation, storage, preservation, canning, fermenting, and other topics relevant to families. NC State Extension's extensive statewide network of county-based agents and campus specialists provided businesses and families with trusted research-based knowledge to prevent foodborne illness.

Nutrition & Health

Project Director

Meredith Weinstein

Organization

North Carolina State University

Accession Number

7000170

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Chronic diseases such as cancer, heart disease, stroke, and diabetes are among the leading causes of death, and in 2017 they accounted for half of all deaths in North Carolina. These 4 conditions accounted for 194,706 hospital admissions (20% of all admissions) and over $9.9 billion in hospital charges (27% of total hospital charges). In 2020 the state ranked 20th in the nation for obesity, with 33.6% of the population obese, and 11th and 12th highest for diabetes and hypertension, respectively. Through a healthy diet and physical activity, many of these chronic conditions are preventable. However, in North Carolina, nearly one-quarter (23%) of adults reported not participating in any physical activities or exercises, 42.3% consume fruit less than once a day, and 22.4% consume vegetables less than once a day. Children are following closely in their footsteps, with only 1 in 4 eating the recommended amounts of fruits and vegetables and almost half spending more than 2 hours watching television each day.

Obesity is referred to as a grave public health threat, a national epidemic, a public health crisis, a global problem, and even a global pandemic. Obesity poses one of the most serious public health challenges of the 21st century. Coupled with obesity there is an increasing rate of food insecurity. NC is ranked the 10th hungriest state in the nation, with nearly 1.5 million NC residents experiencing food insecurity. Almost 1 in 5 children in North Carolina face hunger regularly (24.6%). Food insecurity has increased as a result of the pandemic, amplifying the needs of food-insecure families.

To help North Carolina reduce chronic disease risk and food insecurity, NC State Extension needs to promote policies, environments, and education that sustain healthy behaviors through the consumption of healthy diets, active lifestyles, access to nutritious food and the achievement and maintenance of healthy body weights.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

To promote health and wellness, prevent chronic disease, and increase access to healthy foods, NC State Extension utilized multiple methods and empowered individuals and families to implement behavioral changes focused on healthy eating patterns and physical activity to improve overall health and to use learned strategies, skills, and resources to reduce the risk of chronic disease and illness. As a result of NC State Extension programs, **22,009 adults increased their fruit and vegetable consumption, 7,279 increased their physical activity, and 7,720 consumed less sodium in their diet.**

- NC State Extension Agents made 103,150 **direct educational contacts**, had a **digital media** reach of 94,406,731 and a **mass media** reach of 35,932,627 providing food safety and n**utrition education** information.

- 8,702 adults and 18,383 youth attended **nutrition-related workshops** provided by Extension Family and Consumer Science (FCS) Agents.

- 5,121 adults attended **workshops related to cooking and food preparation** provided by Extension FCS Agents.

- 11,447 hours of service were donated by **Master Food Volunteers**, valued at $297,339; and 7,029 hours of service were donated by **EFNEP volunteers**, valued at $182,613.

Pitt County's EFNEP Educator was concerned that because schools were closed, many youths were suffering from food instability. After receiving notice of an extension of SNAP food benefits, the EFNEP Educator worked to get the word out. The EFNEP Educator reached over 340 people by **posting information on Facebook**. She received phone calls from individuals stating the posting helped them apply and receive the extra food dollars.

Food banks have a difficult time securing meat protein simply because of its cost. At the same time, farmers are dealing with deer damage, and hunters are harvesting more deer than they can consume. Cooperative Extension in Madison County partnered with other nonprofits/food banks, hunter groups, and food processors to **create a system for increasing the amount of venison donated** to food banks. The program included fundraisers, coordination, facilitation, and hands-on assistance and

training in meat handling. As a result, several thousand dollars were raised to pay for the processing of venison, and 4,500 pounds of meat were donated to the local food banks in 2021. This equates to 18,000 meal portions of protein entering the food chain for food-insecure families.

As a result of job loss during the COVID pandemic, many people were struggling to provide meals for their families. All families with children in the Lenoir County Public Schools received a **Pandemic Electronic Benefit Transfer card** (P-EBT card) to support and promote the purchase of fresh local produce. The Lenoir County Farmers Market was able to reinstate the EBT system to accept the P-EBT card. The **Fresh Bucks Program** was implemented, where any customer purchasing with an EBT or P-EBT would receive a match of dollars to spend at the Farmers Market. Cooperative Extension found new ways to support individuals and families experiencing food insecurity and strengthen community capacity to tackle food security challenges through a broad range of community education efforts and by supporting local food distribution hubs. **As a result of NC State Extension efforts, 588,459 pounds of local food were donated for consumption by vulnerable populations.**

Briefly describe how your target audience benefited from your project's activities.

To address hunger during unprecedented times, Extension in Wake County facilitated county-wide COVID-19 **Emergency Food Response** resulting in over 14 million meals being served to food insecure residents since March 2020. The county deployed diverse strategies, including the development and ongoing support of 13 community food distribution points (Emergency Food Hubs) operated by faith partners and nonprofits; an innovative phone app, Tangelo, designed to assist with home grocery delivery; farm gleaning support; summer meal support for children and families; and culturally appropriate Food Boxes for the Latinx population. Collectively, the Emergency Food Hubs distributed 6,833,765 meals since January 2020. In the first 4 months of the Tangelo grocery delivery pilot, 28,364 pounds of food were delivered to 370 food insecure and transportation-limited families.

In Lee County, Cooperative Extension supported food insecure families' access to healthy foods by providing technical expertise to support food distribution to over 700 families per month and distribution of over 500 educational healthy eating card decks to families. ***Through a variety of programs and services, NC State Extension increased access to healthy foods and provided information on healthy eating to food insecure North Carolinians.***

In 2021, **Steps to Health** direct education programs were delivered to 1,273 participants (1,031 youth and 242 adults). Steps to Health promoted policy, system, and environmental change initiatives across 53 sites and communities, 27 of which initiated change strategies that impacted 17,203 NC residents by increasing healthy food options, increasing physical activity opportunities, and encouraging healthy choices. In addition, messaging to support healthy eating and physical activity made 4,511,420 impressions on social media and through social marketing implementation of digital messages and in-store signage. **Take Control**, Steps to Health's chronic disease prevention program reached 242 adults. Across all adult programs, 54% of participants reported improving healthy eating behaviors, and 49% reported improving their physical activity. Steps to Health includes **Color Me Healthy**, a nine-session sensory-rich pre-school nutrition education program that reached 481 children across 20 sites for a total of 3,799 educational contacts, and **Kids Club**, an eight-session nutrition and physical activity program that reached 340 students across 12 sites for a total of 1,676 educational contacts. The Steps to Health **2nd/3rd Grade Program** is a nine-session nutrition education program that encourages students to explore healthy foods from MyPlate and to practice proper handwashing. A total of 143 students participated in the program at 5 school sites with a total of 1,688 educational contacts. Preschool teachers in Columbus County reported that all 53 children that participated in Color Me Healthy improved their willingness to try fruits and vegetables, and many parents commented about their children being willing to try new foods after the class. Across all school-based Steps to Health programs, 29% of participants improved their healthy eating behaviors, 47% improved physical activity, and 46% improved their food choices. **Through Steps to Health, a comprehensive approach to impact the health and nutrition of limited-resource NC residents, Extension delivered nutrition education to food-insecure families and youth while promoting systematic community changes to support healthy living.**

In 2021, **EFNEP** used Zoom, Facebook Live, Google sites, and phone services to serve 1,233 adults and 9,032 youth, 84% of whom were enrolled in one or more food assistance programs. 97% of EFNEP participants improved dietary intake, 85% now practice daily physical activity, 96% practice better food resource management, and 91% have improved their food safety habits. For participating in EFNEP online classes in Franklin County, participants were given fruit and vegetable vouchers. Eighty-five percent of Ashe County School participants reported swapping sugary beverages for water or low-fat milk. In Chowan County, 400 elementary school children received jump ropes to encourage physical activity, and 72% of Chowan County youth participants increased their daily physical activity. A water bottle and lunch bag skill builder was used in Northampton County to help clients be intentional about drinking more water. As a result of the program, a mother and grandmother of 3, now keeps 8-oz. bottles of water in the office to make that her number 1 drink choice. She substitutes healthier snacks, such as fig bars and fruit, for cookies to keep in her desk drawer. She states, "With all of the 8-course lessons, I have learned so many nuggets to keep me more alert and spend my time wisely with my grandchildren. I plan to be more active and alert while running behind my grandkids. With all the great habits I am forming, I can reach my mental and spiritual

goals." **NC State Extension's Expanded Food and Nutrition Education Program (EFNEP) empowered food-insecure families to take charge of their health and economic well-being by teaching families and school-aged youth how to provide nutritious, safe meals on limited budgets.**

Two small NC counties partnered with a regional health system to provide participants with a weekly **Meal Kit** that included all needed ingredients. Participants logged on each week and cooked along with instructors. In another county, an Extension Agent wanted to use a new and innovative approach to provide educational experiences to clientele. Thus, the **Make At-Home Meal Kit program** was initiated. The Extension Agent created and marketed family meal kits featuring the Mediterranean way of eating (Med Instead of Meds). Individuals and families signed up online to pick up healthy dinner kits they could make at home. As a result of this educational outreach, many families ordered the kits and became familiar with eating the healthy Mediterranean way. The director of the largest food bank in the county participated and plans to make healthy meal kits to go for food bank clientele. **NC State Extension used innovative meal kits to deliver nutrition education to families and community members and bring about behavioral changes focused on healthy eating patterns to improve overall health.**

Extension in Burke County delivered the **Cook Smart, Eat Smart** Cooking School in a virtual setting, providing 98 adults across 5 counties with education in basic healthy cooking techniques. Each of the classes included demonstrations of fundamental cooking techniques and tips on eating healthy at home by reading nutrition labels and practicing portion control. Participants received tips for stretching their food budgets while eating healthy foods. Participants reported eating more meals at home, eating more fruits and vegetables, and eating smaller portions. Most participants also reported that the program helped them reduce the amount of money they spend on food. Extension in Gaston County offered 10 virtual workshops on **Healthy Cooking with Herbs** and local, seasonal produce to 468 adults from around the world. Participants reported that the workshops helped them both improve their cooking and eating habits and stay connected to others during the pandemic. **Through NC State Extension cooking programs, clientele used learned strategies, skills, and resources to reduce the risk of chronic disease and illness.**

Briefly describe how the broader public benefited from your project's activities.

North Carolina's **Steps to Health** program is a comprehensive approach that impacts the health and nutrition of limited-resource residents by not only providing Extension-delivered direct education to food-insecure families and youth but also promoting systematic community changes to support healthy living. Policy, systems, and environmental (PSE) changes are a way of modifying environments to make healthy choices practical and available to all community members.

In 2021, Steps to Health promoted PSE change initiatives across 53 sites and communities, 27 of which initiated change strategies during 2021. These changes impacted 17,203 North Carolina residents by increasing healthy food options, increasing physical activity opportunities, and encouraging healthy choices. In addition, messaging to support healthy eating and physical activity made 4,511,420 impressions on social media and through social marketing implementation of digital messages and in-store signage.

The **Communities Moving Together Walk Audit Toolkit** was revised and is now available in North Carolina through Steps to Health. The toolkit can be utilized by Extension educators and community partners throughout the state to support policy, systems, and environmental work to support health in communities that are in most need of resources. Through collaboration with local community partners and leaders as well as local FCS Agents in each county, 3 walk audits were conducted. At each of these walk audits, long and short-term goals were identified, and many of these goals have already been addressed through collaborations between Steps to Health staff, Extension agents, local municipal leaders, and the Department of Transportation. Some highlights include town coordination with the DOT to install pedestrian safety signs to slow through traffic; locating, painting, and restoring benches to provide rest areas for seniors and others along major walkways; and new signage to protect students walking home from schools.

The Gastonia Farmers Market was facing two challenges: they needed to increase the utilization of the market, and they needed find a way to use the market as a location to collect community data. The market manager approached the Cooperative Extension Center in Gaston County seeking assistance. The farmers market, in partnership with the Steps to Health program, utilized the **Policy, Systems, and Environment (PSE) Toolkit for Farmers Markets** to conduct approximately 30 in-person surveys. Staff then created an online survey to target a limited resource community located in proximity to the market. The survey was distributed via email (~50 contacts) to the Community's Neighborhood Advisory group to gather specific information about the interests and behaviors related to the Gastonia Farmers Market. In working through the PSE Toolkit, this project enabled Gaston County to begin data collection, including the completion of the market manager interview, patron surveys, and neighborhood surveys. This data showed an interest in additional seasonal produce such as apples, an interest in expanded produce varieties (including non-local varieties), additional operating hours, and concerns about pricing.

Many areas in Yadkinville, NC are not easily accessible to use for walking or other exercise because they do not have crosswalks, proper signage, space to walk, etc. Yadkin County Extension staff sought to make a difference by reaching out to local 4-H'ers to create an impactful 4-H Summer Enrichment Program to empower youth to help their community. The **Steps to Health Walkability Program** - **Communities Moving Together** was adapted for a youth audience. Youth conducted a walk audit of the city of Yadkinville community and presented their findings to the Yadkin County Commissioners. The Commissioners were so impressed with their work that the findings were presented to the Department of Transportation, and the county plans to implement some of the youth's ideas in the city of Yadkinville area. This event also resulted in 90% of youth participants feeling empowered to be leaders in their community. One parent even exclaimed that her child now wants to go into a career centered around city planning and landscaping to help better communities for those with handicaps.

Led by the local Extension Agent, town and county officials, and residents, a **walk audit** around the Town of Princeville, NC was conducted to assess the walkability of key areas of town. The Extension Agent worked with the mayor of Princeville to address some of the short-term goals, including the need for signage related to the historical locations in the town and encouraging walking at Princeville Elementary. It is anticipated that the entire town of Princeville will be impacted.

Edgecombe County has high rates of poverty and persistent health disparities. Despite persistent health issues, Edgecombe County has significant health assets that can be harnessed. NC State Extension faculty and staff worked with local Cooperative Extension staff to create a **Parks and Recreation Advisory Board** and implement various activities, including 1) increasing the number and promotion of shared-use policies and practices in key community organizations; 2) connecting and promoting vital county and town physical activity resources through wayfinding and signage; 3) support municipalities in improving connectivity between places people live, learn, work, play, and pray through walking and recreation space audits; 4) support and promote walking and biking to and during school; and 5) create and implement a county park and recreation comprehensive plan.

As the need for Americans to be physically active becomes more evident, communities are looking for ways to build environments that encourage outdoor activity. A community member, who was tired of going outside of the county to participate in the newly popular sport of disc golf, approached Cooperative Extension at the Currituck County Rural Center (CCRC) with the suggestion of adding a course to the facility. Together they developed a plan to turn an underutilized space on the property into a disc golf course. After creating a plan to utilize the space, physical disc golf holes needed to be purchased. The volunteer and director of the CCRC acquired sponsorships and donations totaling over $9,000 from outside individuals and area businesses. A complete 18-hole disc golf course was then able to be designed and installed on the county property. In the fall of 2020, this three-year-long project was completed. Thus far, the course has been utilized in two-disc golf tournaments and averages 100 disc golf players per month. This course has not only proven to be a great success for the community but has also brought in new 4-Hers. Six weekly camps for the 4-H youth throughout the summer were held with attendance between 8 and 10 each week. **Currituck County Extension was instrumental in establishing a community disc golf course and improving the quality of life for residents and visitors.**

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

The following professional development workshops were provided by Extension Specialists for Extension Agents in 2021 to facilitate the use and transfer of new research-based knowledge:

- Cook Smart, Eat Smart
- Cooking Essentials, Ingredients for Life
- Coordinate & Plan Nutrition
- EFNEP
- EFNEP Recipes: Guidance for Educators

- Food Labeling Facts and Myths
- Med Instead of Meds
- Pivoting for Maximum Impact: A Case Study Examining Nutrition Education
- Policy, Systems, and Environment Changes
- Steps to Health
- The Students are Hungry, 1 in 4 NC Children are Food Insecure

Websites:

- Health and Nutrition
- Family & Consumer Sciences
- Steps to Health Public and Steps to Health Internal
- EFNEP Public and EFNEP Internal
- Master Food Volunteers

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

Chronic diseases such as cancer, heart disease, stroke, and diabetes are among the leading causes of death. Through a healthy diet and physical activity, many of these chronic conditions are preventable. NC State Extension provides direct nutrition education and promotes policies, systems and environments to support health and wellness, prevent chronic disease, and increase access to healthy foods. Extension utilized multiple methods and empowered individuals and families to implement behavioral changes focused on healthy eating patterns and physical activity to improve overall health and to use learned strategies, skills, and resources to reduce the risk of chronic disease and illness. As a result of NC State Extension programs, 22,009 adults increased their fruit and vegetable consumption, 7,279 increased their physical activity, and 7,720 consumed less sodium in their diet. NC State Extension provided evidence-based information to empower North Carolinians to adopt healthier lifestyles.

Closing Out (end date 09/07/2023)

Reduced-fat Fried Meat Products: Improving the Quality, Safety and Nutrition

Project Director

Reze Tahergorabi

Organization

North Carolina Agricultural and Technical State University

Accession Number
1023325

Reduced-fat Fried Meat Products: Improving the Quality, Safety, and Nutrition

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

High consumption of deep-fat fried foods causes many health conditions including obesity and cardiovascular disease. In this project, we developed a novel frying medium to reduce the fat-uptake in fried chicken and fish. A further attempt was made to enhance the quality and safety of the fried products during storage by using a fiber-rich batter and an edible coating.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

A new frying medium based on an oleogel was prepared to test its effectiveness in reducing the fat uptake in deep-fried chicken. The oleogel was prepared by mixing canola oil and carnauba wax. Chicken breast samples were deep-fried in either canola oil or oleogels. Oleogel-fried samples had significantly lower fat contents than canola oil-fried samples but oleogelation did not improve the oxidative stability of the fried chickens. However, the use of an edible coating with thyme essential oil offered better oxidative stability in the fried samples ($P<0.05$). The edible coating did not alter water activity and pH values in raw samples.

Briefly describe how your target audience benefited from your project's activities.

Undergraduate and graduate students in Food science benefited from this project by gaining hands-on experiences. Graduate students were able to use the obtained results from this project and complete their thesis. Students were also able to publish papers in high-impact journals and present the results at IFT annual meetings as well as other conferences and won first place in the student competition. Faculty members also benefitted from this project as professional development through collaboration.

Briefly describe how the broader public benefited from your project's activities.

Upon completion of this project, the fast-food industry particularly the fried food industry will be able to use the developed novel frying medium to replace the existing commercial frying oils in order to reduce the fat uptake while maintaining the taste and texture of the fried foods. This shelf-stable, low-fat fried meat product with fiber could benefit human health.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

The results have been published in high-impact factor journals indexed in Food Science. We are also planning to share our findings with the public and farmers during the small farm field day which will be held in summer 2022. We will work to complete all the objectives of the project by the termination date of the project which is September 2023.

1. Adrah K., Adegoke S. C., ***Tahergorabi R.** (2022). Physicochemical and Microbial Quality of Coated Raw and Oleogel-Fried Chicken. *LWT-Food Science and Technology*. 112589.

2. Adrah K., Adegoke S. C., ***Tahergorabi R.** (2021). Study of Oleogel as a Frying Medium for Deep-Fried Chicken. *Journal of Food Measurement and Characterization*. *1 -10*. https://doi.org/10.1007/s11694-021-01237-6.

Controlling Insects and Mycotoxins in Stored Corn Grains by Non-Toxic Phytochemicals

Project Director
Jianmei Yu
Organization
North Carolina Agricultural and Technical State University

Accession Number
1019918

Controlling Insects and Mycotoxins in Stored Corn Grains by Non-Toxic Phytochemicals

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Insects and molds/mycotoxins are two major causes of cereal grain loss during storage. They result in food insecurity and food safety issues, and also have significant impacts on farmers and grain processors. This problem is extremely serious in the tropical areas where temperature and humidity are high. This project investigates the potential of some General Recognized as Safe (GRAS) essential oils (EOs) to serve as alternative of synthetic pesticides to control insect infestation, mold growth and mycotoxin production in stored cereal grains.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

During the reporting period of 10/01/2020 to 09/31/2021, we completed objective 2, 3, Task 1 of objective 4, and Task 1 and 2 of Objective 5

Objective 2-3: During this reporting period, we evaluated (1) the attractiveness or repellence of 5 essential oils (cinnamon oil, clove oil, orange terpenes, oregano oil and thyme oil) to the maize weevil using olfactory machine, (2) the insecticidal activities of EOs using corn weevil and organic corn as a model, (3) the insecticidal synergy of two different essential oils against the corn weevil. Each EO was diluted with dimethylsulphoxide (DMSO) to desired concentrations (1%, 5%, 10%, 15% and 20%). Sample treated with 10% DMSO was used as control, and pirimiphos methyl, an insecticide, was used as positive control. The mortality of weevils was measured weekly for 7 weeks.

The olfactory test results show that the ability of each essential oil to attract/repel maize weevil varied with the type of EO. The number of weevils attracted to cinnamon oil was low for all EO concentrations, but the number of weevils attracted by the other essential oils fluctuated greatly with EO concentrations. Therefore, it could be possible that cinnamon oil has the highest capability to repel the weevils among the EOs tested in this study. The insecticidal activity test results indicate the mortality of maize weevil increased with EO concentration and storage time. Cinnamon, clove, and thyme oils were more effective than other EOs. No weevil death was observed at 1% EO, however, at 5%, weevil mortality was 3.3-36% and varied with type of EO and storage time. At 10% or higher concentrations, all tested EO showed comparable or higher insecticidal activity than pirimiphos methyl at its recommended concentration (5mg/kg corn). However, both olfactory tests and insecticidal tests did not show positive synergies between cinnamon oil and clove oil. In summary, all tested essential oils are toxic to maize weevil at concentration 5% and higher, but cinnamon oil is most effective maize weevil expeller and killer. More studies are needed to evaluate the synergy among cinnamon oil and other EOs.

Objective 3-4: Four essential oils (cinnamon, clove, oregano and thyme oils) at concentration of 10% were tested for their anti-fungal activities using a simulated fumigation method. Organic corn grains were adjusted to the desired moisture levels 14% (water activity 0.85) and 16% (water activity 0.9). The essential oils were dissolved in dimethyl sulfoxide (DMSO) to 10%, then added to a cotton ball taped to the lid, the container was capped immediately, and then stored in an incubator at 25 ?C and 35 ?C for 5 weeks. Sample treated with Pyraclostrobin, a EPA approved fungicide for stored corn protection, was used as positive control, and sample treated with DMSO was used as negative control. Samples were taken weekly, aflatoxins including B1, B2, G1 and G2 were extracted and purified, and then determined by ultra-performance liquid chromatography (UPLC) method.

By visual observation, the corn grains in negative controls were molded in one week, but samples treated with fungicide (positive control), cinnamon oil and thyme oil were not molded until week 5. At water activity 0.9 (moisture 16%), alfatoxin B1 and B2 increased with storage time quickly in negative control, but maintained almost unchanged until week 5 in samples treated with cinnamon oil and thyme oil and increased slowly in samples treated with other essential oils. The positive control and all essential oil treated samples showed aflatoxin G1 and G2 levels below the detection limit (0.15 and 0.045 ppb) during the whole storage period, while the G1 and G2 levels in negative control were higher than detection limit. Similar results were obtained for samples stored at 35°C and water activity 0.85. The results indicate that the GRAS essential oils used in this project had some fungicidal activities and cinnamon oil showed comparable fungicidal activity as fungicide Pyraclostrobin. The synergistic effects of EOs on fungal growth and mycotoxin production is under study.

Similarly, the tested essential oils showed different ability to inhibit the growth of mold naturally present in organic corn grains and the production of aflatoxins. Cinnamon oil at concentration of 10% exhibited highest inhibitory potential among all tested essential oils, and similar to that of EPA approved fungicide for stored corn grains. Correspondingly, the levels of aflatoxins in the cinnamon oil treated corn grains were the lowest over the storage period.

Briefly describe how your target audience benefited from your project's activities.

The target audience benefited from your project's activities include (1) grain farmers, processors and consumers who needs to store their cereal grains at warm and humid season for 1-2 months; (2) food and agricultural researchers and extension personnel whose focus areas are food safety and food security; (3) food science students.

Briefly describe how the broader public benefited from your project's activities.

The results obtained during this study period indicate that all essential oils tested had certain insecticidal and fungicidal potential, with cinnamon oil being the most effective in terms of repelling and killing maize weevil, and inhibiting mold growth and aflatoxin production. Cinnamon powder has been widely used in foods as spice and food additive. Cinnamon oil has also been used in cosmetic products and processed foods as flavoring agent, antioxidant and antimicrobial agent. Therefore, cinnamon oil has great potential as a safer alternative of synthetic insecticide and fungicide for insect, mold and mycotoxin control during post-harvest storage of cereal grains, particularly, organic cereal grains in farm storage facility and home, thus protecting the quality and safety of grains and reducing the loss during storage.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Major Changes: Due to the large number of samples from the fungicidal activity study and due to the equipment issue, we only quantified aflatoxins, the most common and most toxic mycotoxins in corn grains, other mycotoxins such fumonisins (FUM), OTA, DON, and ZEA contents of the corn samples were not quantified. However, we saved samples in the freezer. We will have a new HPLC/UPLC system in April 2022. If we can complete the other research activities before the end date of project, we will analyze those mycotoxins.

Student training: Three graduate students were trained during the reporting period.

- Graduate students Sawo Eesiah, her thesis is based on the maize weevil controlling by essential oil. She participated in 2021 Global Food Science Student Virtual Competition and received third place award. She graduated in December 2021.

- Graduate student Ivan Pedroso: She was on non-thesis option and graduated in December 2021. She was trained to conduct experiments on the fungicidal activity of 4 essential oils, record the moldy status of corn grains, extract, purify and analyze aflatoxins.

- Graduate student Esther Iwayemi: She is under training to conduct experiments about the synergistic effects of two different essential oils on mold growth and aflatoxin production. she is expected to graduate in summer 2023.

Dissemination: The research findings were disseminated through class seminar, presentation at North Carolina Center of Environmental Farming System full member meeting, and conference presentations as shown below.

- Jianmei Yu. Insecticidal and Fungicidal Effects of Essential Oils in Stored Cereal Grains. 2021 NC CEFS Spring all member meeting (Virtual). March 26, 2021.

- Jianmei Yu. Controlling Insects and Mycotoxins in Stored Cereal Grains by Essential Oils. Seminar in FCS 789, November 2, 2021.

- Pedroso, I. R., Mikiashvili, N., & Yu, J. Quantification of aflatoxins in organic corn grains by a pre-column derivatization HPLC-FLD method. 2021 Spring ACS National Meeting. April 5-15, 2021.

- Eesiah, S., Amoah, B, Dingha, B., & Yu, J. The insecticidal potentials of some essential oils against maize weevil in stored organic corn grains. IFT21 Virtual Meeting, July 18-21, 2021.

- Mikiashvili, N. & Yu, J. Optimization of extraction and purification procedure for determination of aflatoxins in organic corn grains by HPLC-FLD method. IFT21 Virtual Meeting, July 18-21, 2021

- Eesiah, S., Amoah, B., Mikiashvili, N., Dingha, B., & Yu, J. Insecticidal potentials of some GRAS essential oils against maize weevil in organic corn grains during storage. 2021 Global Food Science Student Virtual Competition, October 17-20, 2021. Submitted on July 28, 2021.

Project Plan: I plan to complete research activities in Objective 4 and 5 during remaining time of this project. Based on the research finding obtained so far, I will submit two manuscripts for publication and one grant proposal for funding to expand the research to the protection of fresh produces using essential oils. The possible funding agencies are USDA-NIFA's AFRI program and CBG program or NC Department of Agriculture and Consumer Services.

Closing Out (end date 09/07/2023)

Protein-polyphenol colloidal aggregate particles for food structure and health functionality

Project Director
Mary Ann Lila
Organization
North Carolina State University
Accession Number
1016487

Protein-enriched processed foods with the benefits of fruit and vegetable consumption required for a healthy population

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Despite stringent and well publicized government dietary guidance, consumers typically under-consume polyphenol-enriched fruits, vegetables and other plant-based foods for a number of cited reasons: dissatisfaction with the astringent, bitter or pungent tastes of polyphenols (e.g. tannic compounds), bulk and perishability of fresh market produce, and/or the inconvenience of having to cook or prepare these foods. Similarly, achieving adequate protein in the diet is a challenge for consumers who are practicing vegan or vegetarian lifestyles, are dieting, or are elderly. Others object to the flavors, density or stiff/hard textures of protein-enriched processed foods. This wide disparity between recommendations for a healthy diet and consumers' actual behavior means that increasing production alone cannot deliver the benefits of fruit and vegetable consumption required for a healthy population.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

The Lilalab orchestrated development of a simple, food-grade strategy to stably bind fruit and vegetable phytoactive constituents with edible proteins to create a concentrated, versatile ingredient (protein-polyphenol aggregates) that can be incorporated into functional foods to deliver bioactive compounds in line with standard dietary guidance, with well-received sensory attributes and flavor. In this reporting year, we thoroughly described the organoleptic and functional properties of the protein-polyphenol aggregates (*Food & Function* 11: 5091-5104), demonstrated the structural functionality of the ingredients to alleviate the well-known industry problem of 'bar hardening' in functional high protein snacks (*LWT Food Science & Technology* 138:110747)ę demonstrated the ability of the aggregate particles to significantly enhance the bioavailability of the phytoactive compounds (*LWT Food Science & Technology* 149: 111901; *Molecules 26*:3781), described and quantified the influence of protein manufacturing processes on the functionality of the particles (*Food Science & Nutrition* 9:3740-3751) and, very importantly, analyzed the foaming capacity and sensory characteristics of the protein-polyphenol ingredients in model food products (*Food Hydrocolloids* 123: 107148)

Briefly describe how your target audience benefited from your project's activities.

Our project work during the reporting year provided concrete and quantitative measurements of the ingredient properties which could directly benefit functional food product manufacturing interests. For the science audience, our work enlightened the community on what to expect from protein-polyphenol particles stably bound together in a food product, and, after ingestion in the gastrointestinal tract.

Briefly describe how the broader public benefited from your project's activities.

The broader public benefits are extended when the aggregate protein-polyphenol particles are incorporated into functional food formulations. During the project reporting period, the particles were used to formulate the intervention in a targeted clinical trial (with well characterized intake of polyphenolic compounds) and were utilized as key ingredients in high protein low sugar gummies.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

The thorough characterization of protein-polyphenol properties has led to professional training opportunities in a protein lab in Raleigh, and, the opportunity for advanced scanning electron microscopy training to critically evaluate the binding properties of the particles.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

Despite their well-publicized health benefits, consumers often avoid consuming fruits, vegetables, and other plant-based foods that contain a high concentration of polyphenols, micronutrients that naturally occur in plants. This is in part because such plant-based foods can have an undesirable taste, they are highly perishable, and they can be inconvenient to prepare. In addition, many consumers avoid protein-enriched processed foods due to dislike of their tastes and textures. To address this challenge, NC State's Lilalab has developed a simple strategy to bind fruit and vegetable nutrients with edible proteins to create a concentrated, versatile ingredient that can be incorporated into foods to enrich their nutritional value while providing a pleasing flavor and texture. Researchers at the Lilalab have already demonstrated the ability of this technique to combat a major industry problem with high-protein snack texture and to enhance the bioavailability of key plant-derived nutrients in enriched foods, and high-protein, low-sugar gummies have been created and used in a targeted clinical trial. Enhancing the consumer appeal of nutrient-dense enriched foods is just part of how we are feeding our future and improving our health.

Implementation of CRISPR-based technologies in food bacteria

Project Director
Rodolphe Barrangou
Organization
North Carolina State University
Accession Number
1013765

Enhanced Food Supply Chain Resilience Through CRISPR Technologies

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Bacteria play important roles in various habitats across planet earth, and have been studied extensively given their roles in human health and disease. A diversity of bacteria are used throughout the food supply chain, notably for fermentation purposes (e.g. cheese and yoghurt) and also as dietary supplements (e.g. probiotics). In this project, we develop and deploy CRISPR-based technologies in food bacteria to alter the genomes and by extension the functional attributes of bacteria used in food products. In the past year, we have harnessed various endogenous CRISPR-Cas systems in probiotic bacteria encompassing *Lactobacillus* and *Bifidobacterium* to decipher and enhance the genetic basis for their health-promoting functionalities.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

The CRISPRlab at NC State is comprised of a dozen scientists including undergraduate students, graduate students and staff members with expertise in microbiology who are developing and deploying molecular tools that enable the manipulation of bacteria used in the human food supply chain. Specifically, we are developing novel technologies that enable the genetic manipulation of food microbes for their use in food fermentations and as probiotics. Besides contributions to the scientific literature, we collaborate with industry and academia to commercialize our technologies and products and also teach and train the next-generation of scientist for fruitful careers in the food, biotech and ag industries.

Briefly describe how your target audience benefited from your project's activities.

There are various stakeholders beneficially impacted by our activities, including students (who graduate and typically get jobs in R&D in the food, biotech and ag industry), collaborators in industry (who benefit from technology and know how transfer to commercialize food bacteria and probiotics used across the food supply chain, notably in dairy products and dietary supplements), and consumers who actually benefit from dairy foods and dietary supplements manufactured using our technologies and bacteria.

Briefly describe how the broader public benefited from your project's activities.

Our patents, know-how and technologies have been deployed commercially with the food and Ag industry to enhance the food supply chain, especially fermented dairy products (yogurt and cheese), to promote human health and nutrition. Some of our genome editing technologies are also being deployed outside of food fermentations in crops, livestock and even trees to breed a more sustainable and resilient food supply chain.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

We have published 20 manuscripts in the scientific literature, given over 50 talks and technical presentations at seminars and scientific conferences, collaborated with start-up companies (TreeCo, Ancilia Biosciences, Provaxus, CRISPR Biotechnologies) and industrial partners (Syngenta, DuPont, BASF). Trainees have developed in the classroom and in the lab, with one MS graduate and one PhD graduate, and all students and lab members have benefited from professional development exposure to our collaborators and industrial partners, which has proven surprisingly efficient with remote and distance-transcending communication media and options dictated by pandemic-related constraints.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

Bacteria play diverse roles in the food supply chain. NC State develops and deploys technologies based on CRISPR, a family of DNA sequences found in bacteria and similar organisms. NC State's patents and expertise have been deployed commercially to enhance the supply of fermented dairy products and promote human health and nutrition. NC State's genome editing technologies are also being deployed in crops, livestock, and even trees to breed a more sustainable, resilient food supply chain. Researchers have published 20 manuscripts, given over 50 talks and technical presentations at seminars and scientific conferences, collaborated with start-up companies and industrial partners, and expanded the training of scientists in food production, biotech, and agriculture. These results exemplify the progress being made through the North Carolina Plant Sciences initiative, a major interdisciplinary effort integrating reserarch and extension designed to address the biggest challenges facing agriculture today.

Food Safety and Nutrition

Project Director

Lauren Hargrave

Organization

North Carolina Agricultural and Technical State University

Accession Number

7001847

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Nutrition insecurity, reflected by poor nutrition, limited physical activity, unsafe food practices, and food insecurity, is a significant national health concern. Poor health disproportionately affects minority and low-income populations. The Expanded Food and Nutrition Education Program (EFNEP) is the nation's first nutrition education program for low-income individuals. It remains at the forefront of nutrition education efforts to reduce nutrition insecurity of low-income families and youth.

Approximately 71% of the total healthcare spending in the United States is associated with care for Americans with more than one chronic condition. The estimated annual medical cost of obesity in the U.S. was $147 billion. The annual medical costs for people who are obese were $1,429 higher than those of average weight. Existing studies show that for every dollar spent to implement programs such as EFNEP and SNAP-Ed, up to $10.64 is saved in healthcare costs.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

EFNEP helps strengthen individuals, families, and communities by teaching nutrition-focused decision-making and resource utilization skills, empowering individuals, families, and communities to be self-reliant, encouraging community engagement, and facilitating employment skills development. EFNEP also promotes teamwork, social responsibility, service, and leadership to support healthy lifestyles among staff, participants, and others. EFNEP commits enough time and resources to impact participants' behavior and enhance social, financial, and human capital.

Through nutrition education, EFNEP helps decrease healthcare costs for diseases associated with obesity, overweight, and other associated conditions, as well as conditions related to poor nutrition, such as anemia, osteoporosis, and developmental delay. EFNEP staffing, education methods, and results help bridge the practical application of nutrition education and nutrition science.

EFNEP helps demonstrate effective educational models, which, in turn, help shape and inform public policy and legislation. In 2021, program assistants provided virtual classes, making the program more accessible to limited-resource families who otherwise could not participate. There were six lessons for youth and nine lessons for adults. These lessons were engaging, focusing on free nutrition education for youth and adults. The hands-on programs teach new skills that can be used at home every daye- from meal planning, grocery shopping, and cooking tips to simple solutions for healthy eating and physical activity.

Briefly describe how your target audience benefited from your project's activities.

EFNEP is currently implemented in Martin, Durham, Vance, Warren, and Guildford counties. A total of 435 participants increased their knowledge of safe home food handling, preservation, or preparation practices and 83 participants developed food safety plans.

Program evaluation findings from 2021 indicated that EFNEP adult graduates made the following improvements:

- 92% improved diet quality.
- 56% increased physical activity.
- 70% increased food safety knowledge.
- 50% increased food security knowledge.
- 81% improved food resource management skills.

Program evaluation findings from 2021 indicated that EFNEP youth graduates made the following improvements:

- 90% improved diet quality.
- 65% increased food safety knowledge.
- 59% increased physical activity.
- 24% increased food security knowledge.
- 58% increased food resource management skills.

Youth in Warren and Vance counties deal with the issue of obesity due to a lack of knowledge about food, nutrition, and food preparation. The lack of food safety skills and the inability to follow recipes results in young people consuming unhealthy snacks and compromising their health. The EFNEP educators in Vance and Warren counties partnered with 4-H agents in both counties to implement the program. Students in grades 3 - 5 were targeted for this camp. Four elementary students attended virtual EFNEP sessions twice a week in June. Vance and Warren County students joined the program every Tuesday and Thursday from 11 am to 12:30 pm. Students were administered pre-surveys in person after signing up for the program. The students submitted their exit surveys virtually. Participants learned culinary skills to prepare authentic Italian cuisines such as Italian-style meatballs, easy vegan ratatouille, skinny pizza, and chicken parmigiana. Students were tested on their recollection of the facts taught throughout the class through platforms such as Kahoots & Menti. Two participants submitted the post evaluations virtually. The skills learned also helped families change behaviors that place them at risk of being overweight and diseases associated with high weight.

Participants completing the lessons improved their nutrition, food behavior, and food safety practices. Seventy-sic percent of EFNEP participants improved in one or more food safety practices. Nutrition practices improved 92%. Participants increased their amount of daily physical activity by 48%. Participants increased fruit consumption by 56%. Participants increased consumption of calcium-rich foods by 58%. Participants also increased vegetable consumption by 59%. Cooperative Extension helps participants learn new skills and strategies to feed their family nutritious meals on a limited budget and improve their overall health. Participants learn to save money at the grocery store. Students learn to eat more meals at home. Youth learn to replace sugary beverages with healthy options, move more every day and use leftovers.

Feedback from participants included the following:

"I learned to sauté vegetables without burning them and I learned to make a pizza from a tortilla," said Camryn, a resident of Manson in rural Warren County and the youngest of five siblings. Her mother, Nikeena Boyd-Kearsy, said that although the camp was virtual, it was immersive and engaging, and her daughter "was cooking actual things people could eat in every class."

"I wasn't very good with knife skills or cooking vegetables without burning them," said Parker, another youth participant. "Now, I cook almost every day, and I'm using the knowledge I learned to get better at it."

The Family and Consumer Sciences agent, the EFNEP programmer, and Vance and Warren County 4-H agents strategized to present pre-teens and teenagers in the local community with a "Chopped" competition to encourage them to increase fruit and vegetable consumption and expand their options to receive more essential nutrients. Eleven youth registered for the program. 93% of youth improved their abilities to choose foods according to Federal Dietary Recommendations. 79% of youth used safe food handling practices more often. 89% of youth enhanced their physical activity practices. 84% of youth improved their ability to prepare simple, nutritious, affordable food.

Briefly describe how the broader public benefited from your project's activities.

N/A

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

N/A

Lifelong Improvements through Fitness Together (LIFT)

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

One-third of adults age 65 and older will fall each year—a fact that is associated with $50 billion in healthcare costs. Falls are among the most common problems facing older adults with impaired balance and mobility. A recent study found that getting more exercise is associated with lower healthcare expenditures. Another study found that physically active adults spend, on average, $920 less on healthcare expenses per year than their inactive counterparts. According to the North Carolina Physical Activity and Obesity profile, 26.4% of North Carolina's adults reported not participating in any physical activity the month prior to the survey.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

LIFT focuses on building strength, flexibility, and improved balance in older adults. The instructor conducts a baseline functional fitness assessment to measure strength, balance, flexibility, and nutrition habits at the program's start. The aim is to improve these areas by the end of the course.

LIFT sessions met for one hour twice a week for eight weeks. For those classes held face-to-face, baseline and post-program functional fitness assessments were completed to measure lower body strength, upper body strength, flexibility, endurance, and balance. The sessions consisted of an active warm-up, eight strength training exercises, and finished with a cool-down, including stretching and balancing.

Many agents shifted LIFT to a virtual format during the pandemic, offering it through Facebook Live and Zoom classes. This shift helped many limited resource families remain active despite many gym facilities closing to reduce infection rates.

Briefly describe how your target audience benefited from your project's activities.

In 2021, there were a total of 540 participants who attended the LIFT program for a total of 129 hours of instruction across nine counties: Alexander, Guilford, Jackson, Martin, Montgomery, Stanley, Swain, Warren, and the Eastern Band of Cherokee Indians (ECBI).

The pre-and-post program strength and endurance assessments showed that, on average, participants improved:

- Lower body strength, as measured by their ability to sit and stand from a chair (an average of three more squats in 30 seconds).
- Upper body strength (an average of five more arm curls in 30 seconds)
- Agility, by reducing the time it took to complete “eight-foot up-and-go” by an average of .16 seconds.
- Lower body flexibility, by being able to reach 1 inch farther toward their toes.

- Upper body flexibility, by being able to rotate their shoulders more (average improvement of 2.4 inches)

- Balance – participants could complete 3.1 of the six balance tests at the beginning of the program. At the eight-week, post-program assessment, participants on average could complete 3.6 of the six balance tests.

- Aerobic endurance improved by an average of 22 steps in two minutes.

In Alexander County, the program focused on eight core exercises implemented over eight weeks, twice a week, combined with nutrition lessons to improve strength and increase fruit and vegetable consumption. In 2020, a virtual four-county LIFT program was implemented, impacting not only the four counties that launched the program but also drawing from seven other surrounding counties. This data indicated that there was a demand for this type of programming. The original agents recruited two more county agents onto the team to meet this demand. Enhanced recruitment doubled the number of participants from 49 in 2020 to 96 across 18 counties in 2021. The team was also able to attract more participants by marketing the program as a county wellness program.

Post survey data indicated that 100% of participants increased their fitness and strength training knowledge. A nutrition component was shared with participants via a weekly follow-up newsletter with an average open rate of 65%, including participants who could not attend the in-person sessions. Post survey data indicated that at least 23% of participants increased their vegetable consumption to three cups per day compared to only 8% at the beginning of the program. Post-tests also showed the number of participants who exercised 30-60 minutes a day increased from 29% to 53%. LIFT empowers these individuals to want to live better. As stated by a past participant, "I walk now with my tummy muscles held in, and I have improved my ability to move my right shoulder and to lift more weight with my right arm. Thank you for helping me to get stronger at my age when so many people my age aren't able to lift, squat, and move like we did during the warm-ups and doing the exercises."

In Jackson County, four people registered for the program, and three completed the entire eight-week program. All three adults who completed the program were over the age of 55. One of the participants engaged in regular high-intensity activity, and the others engaged in regular low to moderate activity. The LIFT program met for two days of strength-based exercise during the week. It encouraged participants to get 150 minutes of moderate cardio activity throughout the rest of the week, along with increasing fruit and vegetable intake. Each participant kept an activity/fruit and vegetable tracker up with for two weeks at a time and turned it in to receive another tracking sheet as needed.

Throughout the program, participants reported they were having an easier time walking the incline in their yard, getting items off the floor, out of storage, or under their bed, and decreased joint pain. Each participant completed a pre-and-post functional fitness test. Each improved in balance by an average of 2.13 seconds, flexibility measured by a sit and reach exercise improved on average by 2.91 inches, and a two-minute step test estimated cardio endurance. The average improvement was 14.3 more steps. The program results indicated that regular meetings in a group setting could help improve activity measures, and forming a community of trust and companionship within your group can help encourage participants to continue meeting and hold them accountable to others. A successful program where the participants felt engaged and encouraged spreads within a rural community by word of mouth. When the program is offered again, and more individuals sign up, the numbers will increase, and more community members will benefit from the program. Once a participant has completed the LIFT program, they can sign back up the next time and do LIFT+, which is the same program structure but more advanced movements to continue their fitness journey. By extension being able to offer this free fitness program, more community members that might otherwise not have the means to afford a gym membership have an option for a group fitness class.

In Montgomery County, the FCS agent partnered with the Brutonville Community Center to offer the LIFT program twice per week for eight weeks. The program included a pre-and-post assessment of physical abilities. Class sessions had exercise and nutritional discussion as well as group interactions. We had 23 participants enrolled in the class, with an average of 8 participants per session. These core participants set a personal goal related to nutrition, physical activity, and program participation. Participants were asked to track their physical activity and fruit and vegetable consumption for the duration of the program. One adult had perfect attendance throughout the course, and 100% of participants improved their lifestyle habits, including eating a variety of fruits and vegetables and eating recommended servings from five food groups daily. Ninety-three percent felt stronger and increased their balance and flexibility. Seventy-eight percent reported being physically active for 30 minutes or more on most days, and all experienced enjoyment in social relationships with others.

Overall, 488 participants increased their physical activity.

Briefly describe how the broader public benefited from your project's activities.

N/A

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

N/A

The Supplemental Nutrition Assistance Program -Education (SNAP-Ed) & Healthy Habits

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

The Supplemental Nutrition Assistance Program-Education (SNAP-Ed) serves limited resource individuals and families nationwide. SNAP-Ed's goal is to assist those eligible for food assistance to make healthy choices the easy choices. SNAP-Ed works to help participants make healthful choices within a limited budget and choose physically active lifestyles consistent with the current Dietary Guidelines for Americans.

Approximately 71% of total healthcare spending in the U.S. is associated with care for Americans with more than one chronic condition. The estimated annual medical cost of obesity in the U.S. was $147 billion. The annual medical costs for people who are obese were $1,429 higher than costs for average weight people. Existing studies show that for every dollar spent to implement programs such as EFNEP, Healthy Habits, and SNAP-Ed education programs, up to $10.64 is saved in healthcare costs.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

SNAP-eligible adults, older adults, and families form the foundation of the Try Healthy community-based programs. All programs are interactive, incorporating hands-on activities, worksheets, games, taste tests, food demonstrations, and discussions. Every participant receives educational extenders to assist in adopting and sustaining behavior change. The Try Healthy program builds on and enhances direct education by providing site-specific resources and engaging site leadership to address policy, system, and environmental (PSE) change. Participants also receive strategies, tips, and interventions to address policies and environments and identify messages that support healthy eating and increased physical activity.

The Healthy Habits program is used in conjunction with SNAP-Ed as a funding supplement to purchase materials that cannot be purchased with other nutritional program funds. The same curriculum is used for both programs. The Healthy Habits program worked with schools and community partners to implement an eight-hour series that promotes healthy living behaviors for youth and their families. The teens-as-teachers model was implemented to assist teens with teaching while building public speaking and leadership skills. With the COVID-19 pandemic, the team pivoted to virtual opportunities.

Briefly describe how your target audience benefited from your project's activities.

243 Participants in the Try Healthy program had the following outcomes based on pre-post surveys:

• 50% of adult participants used the nutrition labels when shopping.

• 45% of adult participants improved their healthy eating behaviors by increasing the number of fruits they consumed.

• 42% of adults showed an increase in the amount of whole grains they consumed.

• 47% of adult participants improved their physical activity behaviors.

Overall, the Try Healthy Program reached 33,101 individuals in 2021.

In Stanley County, the Forsyth County Health Department invited the SNAP-Ed staff to educate on nutrition through the Speedway to Healthy pit stop curriculum as part of their Mass Vaccination Event. Participants were 100 youth ages 5-17, who received their vaccines at the event. They explored the four nutrition booths to learn about MyPlate, the heart, lungs, and mouth. Once they made their way through the booths, they were given a goody bag filled with jump ropes, coloring books, etc. This seven-hour event turned out to be a huge success!

To decrease the risk of obesity and the complications associated with it, the nutrition program assistant in Stanly County brought SNAP-Ed to the classroom. Partnering with the Stanly County School system helped to target youth in a controlled environment where positive new information was received. The Go Glow Grow curriculum, a research-based program, was taught to first graders at Richfield Elementary. This program simplifies MyPlate, which encourages the students to have their plates consist of fruits, vegetables, dairy, protein, and grains. Students received a healthy snack after each lesson, which gave them the chance to try healthy food items. The curriculum incorporates fun and interactive activities that get the students up on their feet to increase physical activity while learning the importance of eating healthy foods. This approach brought excitement to a topic not always discussed in their core classes. Pre-and-post surveys were collected to show the effectiveness of the Go Glow Grow program. The survey results showed that 54% of the students increased their knowledge when identifying healthy foods versus unhealthy foods and understanding which food belongs to each of the five different food groups on the MyPlate diagram. Many of the students gave verbal feedback about how effective the program was for them, such as “I have been eating more fruits and vegetables,” “I ate my apple for lunch,” “I’ve been eating more yogurt,” “I ate the broccoli my parents made last night.” and “I play in the yard when I get home from school.” The nutrition program assistant plans to continue partnering with Stanly County Schools to offer nutrition education programs for youth.

In Greene County, the Family and Consumer Science (FCS) agent partnered with two co-workers from other counties to design the 'Dinner In a SNAP' program. This six-week virtual program was created for limited resource families to teach nutrition education, food safety practices, and physical activities. Participants also learned to make healthy recipes. The Dinner in A SNAP program is a modern and positive contribution to programs aimed at helping limited-resource families in North Carolina. During the series, families learned about nutrition education, participated in a healthy dish cook-along, and tried “move more” activities offered through the LIFT (Lifelong Improvements through Fitness Together) program. Participants were able to:

- Set realistic nutrition and wellness goals for themselves.
- Overcome challenges to eating healthier and moving more.
- Increase fruit and vegetable consumption throughout the day.
- Read food labels to be able to better compare foods.
- Utilize tips on stretching their SNAP dollars.
- Learn how to prepare their meals safely.

A pre-and-post-evaluation was distributed at the first and last sessions to measure knowledge gained from participating in the Dinner In a SNAP sessions. Evaluations found that 85% of the women started setting realistic nutrition and wellness goals after participating in the program.

In Scotland County, the FCS agent and the EFNEP program associate collaborated to offer Teen Cuisine to 26 youth at an afterschool program. Due to the pandemic, we offered the program virtually. The six lessons covered nutrition education, healthy snack taste tests, recipes, and exercise. Session topics were: Eat Smart, You Are What You Eat, Power Up with Breakfast, Find the Fat, Watch Out for Added Sugars, and Snack Attack. A physical activity followed each lesson.

A poll of the participants noted the following knowledge gained from the training:

- The importance of drinking water.
- Lean meats are healthier.
- You can be healthy and have delicious meals.
- How to be cautious with knives and silverware.
- Pizza can be healthy.
- What measurements are and how to use them.
- Exercise is required to be healthy.

Agents in Montgomery County partnered with the Communities in Schools program to offer Teen Cuisine as an afterschool nutrition and food preparation program. Participants met six times for 2 1/2 hours. During the program, 12 youth learned nutrition information (e.g., importance of fruits/vegetables, how to read a nutrition label, the importance of breakfast, whole grains, etc.), food preparation techniques, food safety techniques, and the importance of physical activity. They made and assessed personal health goals during each session and prepared and consumed foods independently. At the end of the program, a Family Celebration night was held, during which students prepared a light meal for their families and shared nutritional knowledge learned during the program. One hundred percent of students increased their knowledge of safe food preparation and nutrition. Class knowledge scores increased from 53% correct to 89% correct at the end of the program. All students reported progressing toward their personal goals - including eating more fruits and vegetables, drinking more water, eating breakfast more often, consuming smarter snacks, and being more physically active. Students reported being thrilled to prepare meals on their own, stating: "I'm so proud of myself and know that I can make healthy decisions." One parent commented, "When we go to the store now, my daughter reads the nutrition labels and tells me what is healthiest for our family." Another parent said, "I'm a single mom, and it's sometimes hard for me to get everything done. Now my daughter helps me in the kitchen, which makes it easier for me to take care of the smaller children."

In 2021 the Healthy Habits program trained seven teen ambassadors during a two-day virtual training, engaged 2,060 youth, and conducted nutritional classes in Cherokee, Guilford, Halifax, Jackson, Montgomery, Pitt, Vance, and Warren counties.

In Montgomery County, the County Health Department partnered with the FCS agent and nutrition educator to deliver a Healthy Summer Contest online series. As part of this series, children and adults were encouraged to submit healthy recipes based on a weekly theme. Every week, winners were announced live on Facebook, and a live recipe demonstration was conducted. Children (from Pre-K through fifth grade) were encouraged to draw pictures of their favorite physical summer activities (e.g., swimming, hiking, jumping on the trampoline). At the end of the series, we combined all recipes into a digital cookbook, illustrated with the children's submissions. A total 111 videos were produced during this series, reaching 4,842 viewers. Participants reported appreciating the nutrition demonstrations and said they tried many recipes at home. The shared digital cookbook increased the number of healthy recipes families could try and encouraged community members to support our local farmers market.

Briefly describe how the broader public benefited from your project's activities.

N/A

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

N/A

Critical Issue

Enriching Youth, Family & Community Well-Being

Improving Pest Management in Urban Ecosystems through Comprehensive Integrated Pest Management Plans

Project Director

Sydney Crawley

Organization

North Carolina State University

Accession Number

1025842

Integrated Pest Management (IPM) in urban environments

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Scientific, logistical, and social/cultural limitations impede the implementation of integrated pest management (IPM) programs in urban structures for both professional and non-professional pesticide applicators. Integrated pest management plans are meant to more effectively control arthropod pests by integrating an array of pest management methods as opposed to pesticide-only approaches. Through a combination of educational needs assessments, product efficacy testing, optimization of scientific communication between specialists and pesticide users, this project strives to expand the adoption of IPM for pesticide applicators in urban ecosystems- especially non-professionals. Information gleaned from this study will be used to inform and improve upon existing IPM programs in urban environments (which will reduce the number of urban pests in structures), mitigate excessive pesticide input (improving human and animal safety), reduce the development of insecticide resistance in urban pests, and a build trust between non-professionals and extension specialists.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

This year, we evaluated three novel products developed by chemical companies and assessed their potential for inclusion in current IPM strategies for ants and rodents. Chemical companies and other entities need mortality and efficacy data for new product registration with the Environmental Protection Agency (EPA). I maintained partnerships with BASF, Bayer, and Syngenta to prepare data packages for the registration of novel insecticidal/pesticidal products and monitoring systems. The availability of new active ingredients and tools for urban pest management will hopefully avoid the development of insecticide resistance and, because the products evaluated were baits and traps as opposed to broad-spectrum pesticides, will reduce chemical input in urban ecosystems. Because the use of pesticides is a critical component in an effective IPM plan, this will give applicators more choices when choosing a product as well.

In 2021, we also worked with Banfield Bio to develop and evaluate a novel trap that captures ticks on their dorsal surface. This project involved a combination of laboratory and field experiments to assess whether our trap was more effective than current, conventional trapping methods (dragging, flagging, etc.). An effective tick trap for multiple species would help pesticide applicators decide when and where to apply pesticides for tick control. Our findings indicated that our trap was as effective, and in some cases more effective, than traditional monitoring methods. These results were published in a peer-reviewed entomology journal. Banfield Bio is currently attempting to commercialize the "Yans" tick trap. With widespread use, this monitoring device would allow municipalities to make more informed decisions surrounding pesticide use for tick

management, reducing the input of pesticides across large areas of land in the United States. Detection and monitoring are the first step of an integrated pest management program, thus, incorporation of this trap into a tick monitoring system will improve IPM programs for tick control in the US, too.

Educating professionals and non-professionals and releasing reliable information for their use is critical to building trust among stakeholders and extension specialists. Thus, we compiled a review paper that assessed bed bug detection and monitoring strategies both historically and at present. We also assessed how product developers may be able to develop more effective monitoring devices, which is a known weak point in IPM programs for bed bug control in structures. This manuscript was released in 2021. It is our hope that the review will prompt the development of better monitoring tools for bed bugs in the future. It has also initiated a partnership between our lab and Banfield Bio that may result in the development of device prototypes.

Finally, we have initiated the development of an educational needs assessment for retailers that sell pesticides in the state of North Carolina. Research indicates that these individuals are who non-professionals rely on for information regarding pest management. However, these individuals are likely non-experts who are not adequately prepared to deliver such information to clients. We plan to use the information obtained from the educational needs assessment to develop curricula for retailers at big box stores for temporary employees that may deliver pest control information to non-professionals on a regular basis. We hope that these programs will increase the likelihood that consumers will engage in IPM practices in the lawn and landscape.

Briefly describe how your target audience benefited from your project's activities.

Because this project is in its early stages (year 1) and the COVID-19 pandemic limited significant interaction among laboratory members and key stakeholders such as pest control technicians, pest management professionals, retailers, property managers, etc., the benefit of current activities has been limited. My target audiences will benefit in the future when I am able to deliver presentations and trainings in person. However, my stakeholders have likely benefited from the publication of unbiased efficacy data regarding monitoring devices such as tick and bed bug traps. My stakeholders, both professional and non-professional, will be able to use these data to make pest management decisions in urban ecosystems. Additionally, professionals and peers (fellow extension specialists) can utilize these data to contribute to best management practices for urban pests. I also utilized these data to make recommendations to pest management professionals desiring to continue their education and receive pesticide applicator credits. They can take this knowledge into the field and apply it when controlling urban pests. Finally, the industry (chemical manufacturers) certainly benefited from efficacy studies conducted in my laboratory, as they will use the efficacy data to register new urban pest control products. Eventually, these products will benefit the broader public when these products are available for professional and consumer use.

Briefly describe how the broader public benefited from your project's activities.

One unique facet of this project is that part of our target audience is the broader public. The non-professional (consumer) pesticide market is valued at approximately 6 billion dollars according to recent market data. Both the rodenticide and insecticide market are growing at an annual rate of approximately 5**%**. In 2021, our focus was on professional stakeholders and building relationships among associations given that I am a new faculty member from another state. However, in 2022, more of our time will be devoted to the public and consumer studies. The public benefit of this study will be immense. Data obtained from the proposed studies will improve pest management for non-professionals, will allow them to spend less on consumer products, will help them distinguish between effective and ineffective pest management practices, as well as apply less pesticide- which will improve human and animal health across the United States.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

The major challenge to the achievement of project goals was the COVID-19 pandemic. Hiring freezes, laboratory shut downs, cancellation of professional meetings, lack of laboratory supplies, and other logistical issues impeded the execution of a number of proposed experiments which required in-person interaction among lab members and stakeholders. We anticipate no further issues as we enter 2022, thus, we plan to accomplish objectives and goals as stated in the original hatch document.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

Integrated pest management (IPM) programs more effectively control pests by integrating an array of pest management methods rather than relying on pesticide-only approaches. NC State researchers evaluated 3 novel products developed by chemical companies and assessed their potential for inclusion in urban structure IPM strategies for ants and rodents. In addition, NC State researchers partnered with Banfield Bio to develop and evaluate a novel trap that captures ticks on their backs and published the results in a peer-reviewed entomology journal. Banfield Bio is currently attempting to commercialize the "Yans" tick trap. With commercialization and widespread use, this device can help municipalities make more informed decisions about pesticide use for tick management, reducing the impact of pesticides across large areas of land in the US. NC State's integrated research and extension IPM program in urban environments is reducing the number of urban pests in structures, mitigating excessive pesticide input and improving human and animal safety, and reducing the development of insecticide resistance in urban pests.

4-H Youth Development

Project Director
Meredith Weinstein
Organization
North Carolina State University
Accession Number
7000171

4-H Programs Provide Opportunities for all Youth to Identify their Passion or "Spark" and Develop Life Skills to be Prepared for Future Success

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

North Carolina has 2.3 million youth under the age of 18 or 22% of the state's population. 561,000 (25%) of those youth live in families that receive public assistance, and 451,103 children (20%) live in poverty. When the pandemic hit, the economic divide increased for many families, especially single mothers, who had to choose between employment and childcare. As schools shifted to virtual learning, the barriers to quality education increased for this population. A number of children also lost stable access to two nutritious meals a day. COVID-19 restrictions also exacerbated mental and physical health issues, leaving children in even greater need of support for a healthy lifestyle. Youth faced increased social isolation and the effects of increased screen time and social media usage.

National reports continue to show that the United States lags woefully behind other nations in STEM (science, technology, engineering, and mathematics) education both at the elementary and secondary levels. In addition, educators often report that students lack understanding and appreciation of the science behind critical fields that fuel individual and societal wellbeing, including technology, agriculture, and horticulture. This creates a continual need to provide students and educators with educational enrichment activities, and this need has been exacerbated by COVID-19 restrictions on hands-on, in-person learning.

4-H, NC State Extension's youth development program, focuses on positive youth development, providing safe experiences that increase the likelihood of enhanced wellbeing and optimal development for participating youth. When combined, the elements of youth "Sparks" - developmental relationships, program quality, and youth engagement create an enriching developmental context for youth participants in 4-H programs. To enhance the well-being and development of youth, there is a need for Extension to provide opportunities for all youth, ages 5 – 18, to identify their passions or Spark and develop life skills that prepare them for future success.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

To help youth develop life skills that will prepare them for future success, NC State Extension provided 4-H Youth Development programs that focused on civic engagement, healthy living, and STEM. In 2021 Extension offered a broad range of in-person and virtual 4-H educational programming. Activities included day camps and overnight camps; clubs; hands-on learning activities in the home, classroom, and community; online educational programs with video lessons and supplementary written materials; and interactive activity kits for children to enjoy during stay-at-home restrictions.

- NC State Extension 4-H Youth Development Specialists maintained 12 **websites** with a reach of 128,068 and created 276 social media posts with a reach of 269,052, providing educational information to educators, parents, and youth.

- 4,660 volunteers received **training** from Extension agents, 2,331 teachers were trained on how to deliver 4-H STEM curriculum, and an additional 4,703 teachers and other stakeholders participated in training provided by Extension Specialists to ensure youth were receiving high-quality delivery of 4-H content.

- NC State Extension 4-H Youth Development Specialists produced 29 **educational videos** viewed by 31,386 youth that provided engaging virtual learning experiences.

- 85,157 hours were donated by 4-H **volunteers**, providing opportunities for youth to work and learn in partnership with caring adults.

Despite COVID-19 restrictions, Cooperative Extension in Chowan County offered 120 second-grade students an opportunity to engage with local agriculture during a **Farm Day Adventure** where they visited a local cotton gin and pumpkin patch and rotated through educational stations on aquaculture, bees, chickens, cotton gin operation, cotton, peanuts, and pumpkins. Bladen County 4-H held a hybrid **Ag'em Up Day** for 392 third-grade students to learn about bee behavior and pollination, crop harvesting, animal husbandry, plant science, and nutrition through an online educational component, and in-person classroom demonstrations and hands-on activities delivered by local FFA and community volunteers. In McDowell County, Cooperative Extension collaborated with local partners to bring an **Agriculture Awareness Field Day** to approximately 1,459 6-8th graders. Students worked through hands-on learning stations covering beekeeping, animal husbandry, aquaculture, agricultural safety, and composting. **Through programs such as these, youth in North Carolina increased their knowledge of agricultural literacy and where their food comes from by using hands-on learning experiences to develop STEM skills that prepare them for future success.**

The **NC 4-H Horse Program** has an estimated 5,309 registered youth participants, 72 horse program-focused clubs, and 200 registered volunteer adult leaders. The program hosted 80 different stakeholder interactions this year through events, training, contests, and activities, with an approximate total of 500 contact hours reaching 1,784 participants. Six state contests were held, some virtual, some in person, with 506 participants, and a national virtual hippology contest with 74 participants from 15 states was created. The horse programs' 222 social media posts reached 170,319 people. The Extension Equine Husbandry website reached 33,543 individuals over the course of the year. **The NC 4-H Horse Program helps youth develop leadership abilities, build character, and assume citizenship responsibilities.** Youth across NC also participated in **livestock, poultry, and small animal** shows and judging; 4-H projects; and clubs among many others. Statewide, youth animal programs had a total of 12,732 youth participants. By participating in showing livestock and other events, youth learned communication skills, work ethic, responsibility, and sportsmanship. **Involving youth in 4-H animal programs helped introduce and inspire youth to consider career opportunities in agriculture.**

In Union County, 4-H launched the **Cool Kids Coding** 4-H club. More than 40 youth learned about robotics and coding using LEGO and robotics projects focused on improving community parks. The club also provided 8-to-14-year-olds with an opportunity to learn a coding technique (word block coding). Union County 4-H also partnered with community organizations to provide **STEM pop-up events** consisting of hands-on instruction at various sites in the county. Nearly 100 youth learned about robotics, electricity, mindfulness, and many other topics through this program. **STEM Educational Kits** were provided to more than 3,000 3rd graders across 147 classrooms. Each kit featured educational lessons and classroom activities focused on the history of agriculture, plant and solar system science, physics, and health science. **Engaging youth in STEM activities is just part of how we are growing future scientists.**

In Cumberland County, Cooperative Extension's 4-H program created 427 **Educational Activity Kits** to help students celebrate Earth Day and learn how they can make a positive impact on the environment. Youth created seed bombs, recycled bee houses, discovered butterfly life cycles, and planted "clover heads" to observe germination and plant growth. Wake County 4-H put together **Camp in a Box Kits** for youth who were home due to schools moving to virtual learning. These activities included experiments around force and motion, weather systems, solar systems, and chemistry. The STEM packets were matched with activity guides for origami, youth yoga, and a gratitude scavenger hunt. Extension staff distributed 900 kits to families in Wake County at food distribution hubs based on GIS maps illustrating the highest-need areas of the county and information about schools with the highest virtual attendance absences and the most disconnected youth. Youth enjoyed valuable STEM-based learning experiences that also provided family engagement. The connections and partnerships made during distribution efforts led to ongoing partnerships with the hubs, resulting in additional programs to serve similar audiences. **NC State Extension's 4-H Agents used activity kits as a way for youth to gain hands-on learning experiences in STEM.**

Over 137 youth participated in the 15 single-day and multi-day camps that were offered by the Edgecombe County Cooperative Extension 4-H **Summer Fun Program**. Educational workshops on livestock management, poultry, embryology, and owl pellet dissection; a Sylvan Bird Park tour; goat yoga, kayaking, and other physical fitness programs; arts and crafts; and electrical projects were offered. Currituck County 4-H offered a robust summer program of workshops and camps for 114 youth. Over 60 **mini-camps** covered a wide array of interests, including biological and environmental sciences, arts and crafts, solar and wind energy, nutrition and food safety, animal and plant sciences, and many fun recreational activities such as sailing and kayaking. **4-H summer day camps were held across the state to provide youth with opportunities to identify their passions or spark and develop life skills for future success.**

Briefly describe how your target audience benefited from your project's activities.

NC State's **4-H Healthy Habits** program uses a 4-pronged approach to strategically leverage the 4-H system to address food access, nutrition, and health equity for underserved youth and families. 583 youth, 116 families, and 34 teen ambassadors participated in the program and were provided with flexible online and in-person learning opportunities. Through the 4-H Health Rocks! program, 4-H helped 1,805 youth develop healthier lifestyles by reducing tobacco, alcohol, e-cigarette/vaping, and drug use. **Youth learned to make healthy choices and live healthy lifestyles by participating in the 4-H Healthy Habits and the Health Rocks! Programs.** The **4-H Empowering Youth and Families Program (EYFP)** is opioid prevention education for middle school-aged youth and their caregivers in rural North Carolina with a focus on providing research-based information about the impact and statistics related to opioid misuse to help youth and families make healthy decisions. After attending the Powerful Communities Program, 75% of 39 youth were better able to discuss difficult situations with their caregivers, and 96% of the 37 caregivers were better able to discuss difficult situations with their youth. Six counties conducted Community Education Events during 2021. Over 4,000 members of the communities involved attended events that addressed opioid misuse, concrete supports, and community agencies. **NC State Extension helped rural families prevent opioid abuse among the youth population.**

In Madison County, 4-H teamed up with middle school health educators to offer a **positive stress management** program to 270 students. Through this program, students were encouraged to identify sources of joy and stress in their lives and develop healthier coping strategies such as gratitude, deep breathing, stretching, and accessing mental health resources. Teachers reported this was one of the most memorable and relevant classes for their students as they advance in their education and gain more responsibilities. In Cabarrus County, 4-H supported student mental health through the **4-H Mindful Me** curriculum delivered to 325 students at 21 after-school centers. Thirty-two after-school teachers received curriculum training and kits to provide hands-on activities with each lesson. Students learned how to build positive relationships through expressing gratitude, self-reflection, and self-control. Teachers reported that students who completed the course could more easily discuss their feelings in a constructive way, expressed more positive emotions, and displayed improved focus in the classroom. **NC State's 4-H programs supported students' mental health through stress management and mindfulness activities.**

In Surry County, 4-H worked with a local middle school to provide 135 6th-8th grade students with **life skills** lessons on decision-making, goal setting, time management, study skills, problem-solving, leadership, self-motivation, communication, organization, and resume and interview skills. After this program, 90% of 6th graders, 86% of 7th graders, and 92% of 8th-grade students answered "yes" or "maybe" when asked whether they felt more prepared for their future academic and occupational careers. Surveyed students also reported improved self-understanding, time management, confidence, and planning skills. **As the leader in experiential education, NC State Extension provided relevant opportunities for students to put learning into practice and develop personal and career-ready skills.**

The 4th-grade teachers at a Cherokee County elementary school wanted to re-introduce hands-on learning, which had been restricted due to COVID-19. After using the **4-H Magic of Electricity** school enrichment curriculum, the teachers observed that students had a better understanding of electricity and the scientific method when they were able to "learn by doing." The 5th-grade science teacher also observed that current 5th graders had a weaker understanding of the scientific method than past students who had been exposed to the 4-H school enrichment curriculum. Through this 4-H experiential learning process, 34 students learned about the scientific method and the basic concepts of electricity. After the activity, the teachers had students choose one of the activities and describe the scientific method used to obtain the results of the activity. The teachers observed that the students had a better understanding of the scientific method than the students in 2020 and believe that the students will be more successful in their future science classes because they participated in the 4-H School Enrichment program. **Through 4-H science activities, youth learned skills that prepare them for the STEM jobs of the future.**

4-H offers an innovative embryology school enrichment program that teaches 2nd-grade students about the life cycles of poultry while fostering understanding and appreciation of agriculture and science. In 2021, the **4-H Embryology Program** was delivered by Extension agents and teachers in 54 counties to over 56,000 students using a combination of in-person, online, and hybrid lessons. Students were able to watch the development and hatching of chicks either in person or through videos,

and some students were able to engage in hands-on learning activities, such as recording observations, turning eggs, and controlling temperature and humidity levels. Online support materials were provided, including worksheets, puzzles, and recipes. In Henderson County, teachers reported that 98% of students improved their basic knowledge of science through this program, and 96% improved their math skills. Robeson County teachers reported that 75% of students improved their knowledge of science terminology and improved their science grades after participating in this program. **Science-focused school enrichment programs provided youth the opportunity to learn about science, technology, engineering, and math (STEM) through fun, hands-on activities.**

4-H horticulture programs continued to help students learn about gardening and healthy living in 2021. Through hands-on activities, the **Just Grow It!** program taught youth about growing and harvesting vegetables, pest management, food safety, and healthy home cooking with produce. Over 650 youth in 52 counties participated in Just Grow It. Youth overwhelmingly increased their knowledge of gardening, insects, the soil and the need to steward the environment. Positive attitudes toward science, nature, and environmental stewardship grew, and evaluation data suggested that they would do more to engage in these areas. More than 50% of the youth that participated were new to 4-H. As a result of the program, students were comfortable spending time in the garden, often spent time with their family outside or in the garden and increased their passion for science. In Bladen County, Cooperative Extension created a **virtualo school garden** for 300 4th-grade students, provided educational packets, a Google site with videos and content for each session, and game-based learning challenges. This hybrid program allowed students to plant and manage their crops at participating schools while benefiting from weekly video lessons on best practices for managing garden crops. 90% of students reported increased knowledge of plant science and nutrition, and more than 90% indicated that they are now either confident or very confident about their ability to plant and maintain a garden at school or at home. In Cleveland County, 4-H provided 800 students with their own succulent **plant to care for** and a care instruction card. Teachers were given supplementary resources to teach their students about plant science and horticulture. Student and teacher participants reported not only improved knowledge of plant science but also stress relief benefits from caring for their plant daily. **Through 4-H horticulture activities, youth learned skills that prepare them for the STEM jobs of the future.**

Briefly describe how the broader public benefited from your project's activities.

A ten-year longitudinal study conducted by Tufts University discovered that the structured out-of-school time learning, leadership experiences, and adult mentoring from 4-H experiences play a vital role in helping youth achieve success. The study found that compared to their peers, youth involved in 4-H programs are nearly 4X more likely to make contributions to their communities, and about 2X more likely to be civically active.

North Carolina's youth who participate in 4-H service projects and leadership roles learned about civic affairs and developed public speaking, leadership, and decision-making skills. These youth learned to advocate for themselves and others about the importance of giving back. Cooperative Extension's 4-H civic engagement programs empower young people to become well-informed citizens who actively contribute to their communities and the world. Extension provided an array of programs to promote civic engagement among youth to improve the quality of life in our communities today as well as in the future. A sample of these activities follows.

To promote youth confidence, healthy development, and civic engagement, NC State Extension's #PassTheMicYouth, a youth-led podcast and blog that shines a spotlight on youth development and activism, pilot-tested a 20-lesson curriculum focused on engaging young people to develop a critical awareness of social issues so that they can participate in informed action through creative expression and coalition building. The new curriculum reached approximately 75 youth and 13 facilitators. In 2021, this program helped launch 6 youth-led podcasts by providing resources and targeted consultations. Wake County engaged a mental health partner in the program to add an additional program component. The combined mental health, youth development, and social justice expertise enabled the team to launch a program that met the needs and interests of 21 urban youth. #PassTheMic created a space for youth to use their voices and connect and encouraged youth to have a voice in their community. citizens and public servants.

Cooperative Extension worked with Wake County public health to develop a COVID-19 Youth Council to engage youth in peer advocacy and address pandemic concerns. Seventy-four high schoolers answered the call and signed up to participate. The group developed 9 TV spots to encourage teens to get vaccinated and tested for COVID-19. The promotions were aired during local tv coverage of high school football games, attracting a total viewership of at least 9,000.

The 4-H Ambassador program empowered teen 4-H leaders with the knowledge, skills, and aspirations necessary to be an effective advocate for 4-H. The program strengthened and expanded upon 4-H Ambassadors' current leadership abilities so that they could serve as positive role models for younger youth; build meaningful partnerships with other teens, adult volunteers, and 4-H professionals; and promote the 4-H mission in NC. In 2021, 51 youth participated in the training program, gaining knowledge in public speaking, youth development, etiquette, life skills, experiential learning, leadership, marketing,

civics, and diversity and inclusion. In addition to class participation, 28 youth completed an additional 580 hours of elective activities consisting of leadership, citizenship, and community service. Twenty-eight youth completed their ambassador achievement portfolios and were recognized during the 4-H Congress.

Extension also provided opportunities for youth to perform Community Service Projects as a way to teach youth the importance of giving back. In Caldwell County, 3 youth completed projects, including the creation of 44 denim dog toys for a local pet rescue and the distribution of 60 joke books and 180 Valentine's Day cards to senior citizens, many of whom were experiencing isolation during the COVID-19 pandemic. One parent said of her son, "He has developed some permanent qualities that I'm so proud of e picking up trash, helping the neighbors, helping at home." Johnston County 4-H'ers and multiple FFA chapters helped collect food items for the Backpack Buddies program, which provides easy-open, ready-to-eat food for youth when they are not in school. In total, 1,217 pounds of non-perishable food were collected to help ensure that a child did not go hungry during the holidays and taught the youth involved about community service.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

In the summer of 2021, 4-H camps enrolled a total of 1,382 youth, a 50% decrease from 2019 due to COVID-19's reduced capacity. However, over 2,000 COVID tests were completed thanks to 4-H agents, camper parents, and summer camp staff, and 136 youth from vulnerable populations were able to attend camp through scholarships. In addition, 4-H reached out to youth at home through educational activity kits, day camps, and hands-on, social-distancing-friendly outdoor activities were provided for smaller groups.

The following professional development workshops were provided by Extension Specialists for Extension Agents in 2021 to facilitate the use and transfer of new research-based knowledge:

- #PassTheMic: A Curriculum to Amplify Youth Voices
- 4-H and Citizen Science. It's Connected
- 4-H Camp Marketing & Recruitment 101
- 4-H Prof.& LGBTQ+ Youth: Examining Results from an NC Study
- Centering DEI in Youth Programs
- Cooking Up Confidence: Science w/ Your Snacks
- Developing youth entrepreneurship using mind-maps techniques
- Farm Safety Fun for 4-H: Hands-On Lessons about Farming Hazards
- Finances Matter: Financial Management for Teens!
- Incorporating Purpose Development in Youth Programs

- Kids Voting: Engaging Citizenship Activities for All Ages
- Soil to Seed
- Strategic Marketing for 4-H
- Understanding the 4th "H"

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

NC State Extension's 4-H Youth Development program focuses on positive youth development, by providing safe experiences that increase the likelihood of enhanced wellbeing and optimal development for participating youth. To enhance the well-being and development of youth, Extension provides opportunities for all youth, ages 5-18, to identify their passions or "Sparks" and develop life skills that prepare them for future success. NC State Extension provided 4-H Youth Development programs focused on civic engagement, healthy living, and STEM. In 2021, Extension offered a broad range of in-person and virtual 4-H educational programming. Activities included day and overnight camps, clubs, hands-on learning activities (or interactive kits) that could be completed in the home, classroom, or community, and online educational programs with video lessons. Even with the challenges of being in the midst of a pandemic, 4-H continued to empower youth to reach their full potential by providing opportunities for "Learning by Doing".

Community Development

Project Director

Meredith Weinstein

Organization

North Carolina State University

Accession Number

7000080

Leadership Development and Partnership Building

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

North Carolina's community well-being is built on a foundation of inclusive, empowered leadership and productive decision-making. NC has vast untapped potential and resources in its leaders, organizational governance, community decision making, and collaborations. Today's communities face issues too complex to be solved by community leaders using methods that preserve the status quo. Communities need more diverse leadership with new and innovative ideas. NC communities face intricate issues like economic mobility, bridging the rural-urban divide, and reconnecting to our communities that require engaging a diverse group of Extension clientele to serve as a resource to address these challenging issues. It also requires building leadership capacity and working alongside these community leaders to implement change. Communities can build capacity for civic dialog on complex issues and make leadership groups more productive and inclusive to create opportunities for partnership and collaboration and optimize community wellbeing.

As national, state, and county leaders contemplate a return to normalcy or a "new normal" from the COVID-19 pandemic, Extension leaders and staff are hopeful that the lessons of the pandemic might be incorporated into long-term actions, mindsets, and systems changes. As local communities and governments deal with the ongoing challenges of the pandemic, and as communities grow and become more urbanized, Extension must adapt to rapidly evolving needs by developing its staff, leaders, and partners. Fostering local-state partnerships is essential to Extension's effectiveness, and it can be difficult to collaborate, strategize, and share complex county workloads with partners.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

In 2021, Extension supported leadership development and partnership building by providing specialized training; hosting in-person, virtual, and hybrid educational programs and presentations; and proactively engaging with a broad range of stakeholders, including community leaders, educators, growers, and consumers.

Professional, external organizations wish to tap into the expertise of NC State University to provide their employees with ongoing professional development opportunities beyond undergraduate and graduate degrees. NC State Executive Education coordinates with external clients, organizations, NC State faculty, staff, and external subject matter experts to develop and provide learning and development programs for clients' employees in a variety of areas. NC State Extension Specialists held two training programs with **military personnel** from Ft. Bragg with a total of 46 participants. In this program, participants explored new models for effective team practices and processes, developed personal skills in influencing effective team behavior and identified specific applications to improve organizational outcomes. In another program, **Women in Technical Leadership**, a networking session was held with 17 participants. This program taught high-potential businesswomen in STEM fields specific strategies and tools needed to demonstrate and communicate their value more effectively to key stakeholders and expand their portfolio of leadership experiences in their field.

The North Carolina Tobacco Trust Fund Commission **Agricultural Leadership Program** develops the leadership skills of North Carolina agriculturalists. The diversity of agriculture in North Carolina and agriculture being the #1 industry make it important to develop leaders who are willing to lead within their agricultural organizations, farms, and communities. This program assists in meeting this demand. Following each session, participants were asked to submit feedback on the session and share if there were any significant changes in their thinking, agricultural awareness, and leadership. By exposing participants to different realms of agriculture throughout the state, participants indicated their agricultural knowledge increased significantly. Agricultural issues that they once thought were unrelated to them or their industry they now realize are important for a united agriculture community that supports each other.

To better prepare **agriculture education teachers**, workshops were designed to meet their needs. These workshops focused on topics such as instructional strategies, teaching diverse learners, and working with colleagues. Based on the evaluations, teachers indicated an increase in knowledge and gaining resources they can easily replicate in their classrooms and programs.

Early career Extension professionals need focused training to develop leadership skills that support their work as change agents helping their communities address big, messy challenges (adaptive leadership) while ensuring that their process is democratic and their outcomes increase justice and equity. The **Agents for Change** program launched in January of 2021 with 15 professionals (4-H, FCS, Horticulture) to develop leadership capacity, the development of a project that applies these capacities in their communities, and access to one-on-one or small group meetings for troubleshooting or personalized support. Fourteen of the 15 cohort members have completed year 1 and are engaging in year 2. Preliminary results indicate growth in adaptive leadership and transformative leadership capacity.

Briefly describe how your target audience benefited from your project's activities.

To support leadership development in Durham County, accommodate an increasing need for trained facilitators, and enhance public-private collaboration Extension created a virtual adaptation of **Facilitation 101 Training** for county employees. The format was changed from a 1-day in-person workshop to a 3-day training in shorter increments held via Zoom. The new virtual format incorporated practice meetings with coaches utilizing breakout rooms. In February 2021, 36 county staff participated in the training, received in-depth coaching and feedback, and had opportunities to use a mock meeting to practice facilitation roles. Nearly 100% of the participants found that the training helped them improve their virtual facilitation skills. **NC State Extension strengthens communities by increasing the knowledge and skills of community leaders.**

Cooperative Extension collaborated with local partners to provide 18 Chatham County Chamber of Commerce Leadership Academy participants with a **traveling tour of local Chatham County farms and agribusinesses**. Participants were introduced to a variety of agriculture types for which the county is best known, such as greenhouse and community supported agriculture (CSA) production, grass-fed beef cattle production, and native plant nursery production. Post-evaluations revealed that participants greatly enhanced their knowledge of the economic impact and the diversity of agriculture and agribusiness. As a result, 100% of tour participants expressed a greater appreciation for agriculture and its role in the economy. The participants also reported intention to seek out opportunities to support local agriculture from both monetary and advocacy standpoints. Some participants have even volunteered with local producers to help harvest/glean produce to share with local food pantries. Other leadership academy participants have directed their staff and clientele to the Extension office for technical guidance and assistance. **NC State Extension grows communities by increasing the knowledge and skills of community volunteers and leaders.**

To engage with the local African American community, Cooperative Extension in New Hanover County partnered with the Friends of the Arboretum Board to launch a joint celebration of Black History Month and a **showcase of local black-owned businesses** in February 2021. The businesses were promoted through signage in the public garden and social media posts, culminating in a Sunday afternoon reception attended by 30 individuals. The informal gathering resulted in several lasting relationships and a planning team for a Juneteenth Festival at the Arboretum. The **Juneteenth Festival** was held with 18 vendors, music, dancing, a student reading of the Emancipation Proclamation, and more for an audience of over 500 attendees. One of the respected community leaders in attendance, a black male, spoke to the director following the event, saying "I have lived in Wilmington for a long time, but this is the first time that I have ever felt welcomed here." Informal observations 6 months later show that an average of 20% of Arboretum visitors are black, a good parity representation of the county's population. **NC State Extension strengthens communities by expanding the reach and increasing inclusive engagement.**

Briefly describe how the broader public benefited from your project's activities.

Cooperative Extension engaged with the Gaston Together **Health in All Policies (HiAP)** program to help local governments and community partners integrate health and equity into their policies and programs to advance the health of Gaston County residents. The effort envisions land use planning, economic opportunities, active transportation, access to parks, violence prevention, healthy food systems, and education that create healthy opportunities for all residents to live, work, learn, and play. Gaston County Extension chaired the HiAP committee and involved partner organizations and planning departments from 8 municipalities to organize a HiAP virtual workshop in May 2021 to prepare diverse professionals and community members to understand HiAP, form collaborative community teams, create community work plans to build policies and programs that enhance health and equity, and integrate HiAP into their program planning and reviews. Extension efforts build organizational capacity to accomplish goals through training and technical assistance in strategic planning, governance, and facilitating complex decision-making. A total of 56 planners and community partners participated in the workshop, and participants reported an increased ability to incorporate HiAP into community decision-making. As a result of the workshop, a permanent HiAP work team was created and is currently developing a Health Assessment Tool to assist in planning decisions by local governments. **Extension agents work with community groups and coalitions to increase collaborative practices and effectiveness, amplifying the capacity of NC's leaders, organizations, and communities to ensure sustainable and equitable prosperity for all North Carolinians.**

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

The following professional development workshops were provided by Extension Specialists for Extension Agents in 2021 to facilitate the use and transfer of new research-based knowledge:

- Disaster Preparedness and Recovery Training

- Extension's Role in Disaster Management and Community Resilience

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

North Carolina's community well-being is built on a foundation of inclusive, empowered leadership and productive decision-making. NC has vast untapped potential and resources in its leaders, organizational governance, community decision making, and collaborations. Extension supported leadership development and partnership building by providing specialized training; hosting in-person, virtual, and hybrid educational programs and presentations; and proactively engaging with a broad range of stakeholders, including community leaders, educators, growers, and consumers. NC State Extension worked with community groups and coalitions to increase collaborative practices and effectiveness, amplifying the capacity of NC's leaders, organizations, and communities to ensure sustainable and equitable prosperity for all North Carolinians.

Community Infrastructure

Project Director

Meredith Weinstein
Organization
North Carolina State University
Accession Number
7000082

Strengthening Community Infrastructure and Resilience to Build Future Economic, Health, and Social Well-Being

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

North Carolina is changing rapidly. An increase in climate events, shifting climate patterns, changes in state demographics, shifts in living patterns, and the influx of migrant workers create a need for disaster preparedness, health and safety education, and financial literacy and planning. Evidence of rural stress, broadband connectivity rates, and utilization, number of communities needing upgraded infrastructure and services affect the state's opportunities to attract new businesses and residents.

The COVID-19 pandemic tested community and government infrastructure at every level, creating unprecedented challenges associated with public health, food security, working conditions, and much more. Essential workers and economically disadvantaged populations were particularly vulnerable. Within a year of the declaration of a global pandemic for COVID-19, many resources were available to protect people from infection, but state agencies did not have the local relationships to get these resources to people across the state. Access also felt very urban-centric, and rural reach was vital in protecting NC's population. The rural population was also hit hard as schools continued to operate in virtual learning environments. Many rural areas of the state lack the broadband infrastructure to support high-speed internet access.

The onset of the COVID-19 pandemic coincided with the time of year that farmworkers generally arrive in NC. The close working and living conditions and frequent communication barriers experienced by migrant farmworkers made them even more vulnerable to infection. Farmers are highly dependent on these workers to plant, harvest, and manage perishable crops on time. A 2-week illness and quarantine of multiple workers could be financially devastating to a farm operation and the security of local food systems. Due to the COVID-19 pandemic, personal protective equipment also became scarce and expensive, and essential businesses found it difficult to protect their employees and consumers. 2021 marked the second year of the COVID-19 global pandemic. As the year began, vaccines were just becoming available, and there was tremendous uptake. During this time, disinformation campaigns were rampant, trying to dissuade people from getting vaccinated.

NC State Extension programs are in a position to help to strengthen NC's infrastructure and resilience, build on technological opportunity, and meet rapidly shifting climate impacts, demographics, workforce health and safety, and consumer demands that build the future economic, health, and social well-being of NC communities.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

The Social & Economic Vitality (SEV) Program of Cooperative Extension Wake County Center partnered with several organizations to reduce the community spread of COVID-19. With the support of local partners, Extension staff mobilized a community-led response that paired **mask distribution** efforts with **food and clothing distributions** to offset the impact of the pandemic in vulnerable communities. Over 290,000 cloth and disposable masks and over 150,000 personal bottles of **hand sanitizer** were distributed in the community through the partnership. In addition, Extension coordinated weekly food deliveries directly to homes and community centers, ensuring that thousands of pounds of food were provided to families in need during the pandemic. **Extension leveraged existing partnerships to distribute masks, hand sanitizer, and food to families in need during the pandemic.**

Migrant and seasonal farmworkers experience significant health inequities, compared to non-agricultural workers. To reduce these health inequities, NC State Extension worked to improve infrastructure and reduce health literacy barriers among migrant and seasonal farmworkers by improving the availability of culturally appropriate and evidence-based health information materials relating to farmworker health; increasing health information literacy skills and knowledge of resources among NC's farmworker-serving community health workers; and providing internet to farmworker camps and farmworker youth-serving organizations. Extension published a mapping review of the literature which contains 1,040 records, and identified, organized topically, and evaluated 773 health education materials for farm workers and their families. In addition, Extension conducted 3 focus group discussions with 28 farmworker-serving community health workers across the state; distributed 22 pieces of technology (e.g., megaphones, TVs, tablets, projectors, audio PA systems, and tripods for health

education) to 12 sites; created 8 videos (4 in English, 4 in Spanish) on topics like searching and evaluating health information online; and provided 3 webinars to 61 total participants on technology and farmworker educational materials, finding online health information, and designing educational materials. Extension also partnered with community organizations to provide Chromebooks and hotspots for dissemination. **Extension played a key role in ensuring that the migrant farmworker community had access to culturally appropriate science-based health information and resources.**

Briefly describe how your target audience benefited from your project's activities.

By leveraging 101 local Extension Centers across the state, each of which cultivates relationships with most of the state's farmers, Extension played a critical role in rolling out the North Carolina Department of Health and Human Services (NCHHS)'s plan to reach every farm in the state with COVID-19 response resources, including **vaccinations**. NC State Extension participated in **COVID-19 task forces** across NC's farming governmental and nonprofit agencies to coordinate additional support for farmworkers. The local capacity of Extension across the state provided great flexibility in how individual teams functioned to maximize results. Extension appointed contacts in every office to lead local teams that helped make vaccination accessible to farms. Agents contacted farmers, provided information, communicated with health providers, and completed NCDHHS's weekly data reports. Agents also worked with partners in the event of a breakout of infection to provide resources and promote strategies to reduce breakout size and impact. Through coordinated efforts, 21,947 doses of the COVID-19 vaccine were provided by local teams.

The partnership's ability to maximize results has led to an additional contract for $614,000 from NCDHHS to continue the work and hire 5 Extension COVID-19 Regional Educators, greatly growing the NC Farmworker health and safety program. Extension also **distributed 585,970 masks, pallets of hand sanitizer, cleaning supplies, and toiletries to farmworkers**. All PPE came with educational materials to be posted on-farm and given to workers to promote proper usage and prevention strategies. **Through existing partnerships, Extension was able to quickly provide needed equipment and education to NC's farms and their workers.**

Cooperative Extension also provided much-needed extra support to Spanish-speaking migrant farmworkers. Ashe County Extension used its trusted community relationships to **spread information in English and Spanish about the importance of early vaccination, testing and quarantining**. Because farmworkers were provided with science-based education in their native language, they were able to individually determine the best course of action, and by the end of 2021, the Latino population in Ashe County had an 18% higher vaccination rate than the non-Latino population, at almost 70% of the population fully vaccinated. **In addition to preserving the health and safety of this vulnerable population, this effort ensured that Ashe County's Christmas tree industry remained the largest economic sector in the county and experienced minimal financial impact from COVID-19.**

After vaccinating over 300 Hispanic workers and their families in the spring of 2021, it was a natural progression for Extension in Avery and Watauga Counties to work with partners at the beginning of the Christmas tree harvest season to launch a fall mass **booster vaccination clinic**. The High Country Farm Worker Health program, High Country Community Health, and Avery and Watauga County Cooperative Extension Centers worked together to provide 299 **COVID-19 booster shots** and 112 **flu shots** at these clinics. Extension provided the vaccination spaces in Avery County and made appointments to facilitate the vaccination process. Thanks to this clinic, over 88% of Latino farmworkers in these counties were fully vaccinated against COVID-19, and no workers during the harvest season lost any work time due to COVID. Many H2A farmworkers commented that they wanted the vaccination to protect their families when they return home, as vaccines were difficult to receive in their home country. **This cooperative effort not only provided necessary health education and services to our H2A guest workers but also ensured a healthy harvest.**

Cooperative Extension in Wake County convened a team with the County Health Department and a Hispanic serving organization to locate farmers in the area with H2A workers, contact them, and **deliver vaccines to their farms**. This effort was broadened to migrant workers, generally of Hispanic descent, and their families. As a result of Extension efforts with local partners, about 350 people were vaccinated, mainly H2A and migrant workers. The Extension agriculture agent established new relationships and strengthen existing ones with local growers. The team discovered a need for more medical-related support for migrant and H2A workers which has led to ongoing discussions to expand medical support for this population across the county.

Cooperative Extension also partnered with the NC Department of Health and Human Services, the Rowan County Department of Health, Rowan Emergency Services, and the Rowan Cabarrus Community Health Clinic to arrange **vaccine clinics for farmworkers**. Initial and follow-up clinics were set up near major H2A visa employers. By partnering with DHHS and the Rowan Cabarrus Community Health Clinic, Rowan County was able to fully vaccinate 584 farmworkers.

The Anson County Extension Agent and community partners coordinated **on-farm vaccination clinics** for Anson County farms. The Extension Agent sent out mailings to farms about the availability of vaccines and advocated for each farm interested. Times and days were carefully selected to minimize the impact on farm operations. Nurses, with the assistance of translators, were able to educate and inform the workers about the vaccine and its potential side effects. Over four days in May and June, 98 workers received their first and second doses of the vaccine.

With the support of local partners, Cooperative Extension in Nash County used **farmworker outreach** during the pandemic as an opportunity to provide migrant workers with a weekly **Health Fair**, which ran for 9 weekly sessions. In addition to delivering 159 **COVID-19 rapid tests**, the fair provided **CSA boxes** to 281 people, as well as **health screenings** (135 blood pressure checks and 133 blood sugar checks), and **educational resources** to farmworkers and the community. **Through a partnership with the NC Department of Health and Human Services and other community organizations, Extension led efforts across the state to ensure the health and well-being of farmworkers and prevented significant disruption in agriculture production through vaccine distribution efforts.**

Briefly describe how the broader public benefited from your project's activities.

Tractors guided by GPS, cows milked by robots, data collected by drones to pinpoint where and when to use water, fertilizer, and pesticides, even biosensors that monitor animal health, with every passing year, North Carolina farmers increasingly turn to advanced technology to reduce losses, raise yields, and limit their impact on the environment. But they face obstacles. One of the most talked-about these days is the lack of affordable high-speed internet connections, or the lack of high-speed internet entirely, in some rural areas. Farms are businesses. And as with many other businesses, the technology they need to maintain profitability has evolved exponentially. So has the need to gather data and put it to use. NC State Extension plays an important role in broadband access, adoption, and utilization across North Carolina by focusing on ways to use broadband resources beyond entertainment and connection; and to increase opportunities in education, productivity, wellness, and commerce.

Responding to the growing need for NC State Extension to be involved in rural broadband issues, a Broadband Access and Education Coordinator position was developed. A broadband resources webpage outlining broadband resources by Extension programming area was created to help Extension personnel find an on-ramp for working on broadband in their Extension subject area of expertise. In addition to the resource page, other resources helpful to the mission of NC State Extension are curated and posted on the Community Development Portal. Training has been conducted to build the capacity of Extension Agents. These broadband resources provide NC State Extension Agents and Specialists with research-based knowledge that can be extended to their communities helping transform science into everyday solutions that improve lives and grow our state.

The NC Agriculture Digital Alliance provides an avenue for partners to learn, share, and collaborate to support digital inclusion and equity among the agricultural community. This includes sharing models and funding opportunities, finalizing a broadband and agriculture mapping project, and collectively completing a digital literacy assessment for agricultural communities inclusive of farmers, farmworkers, and family members. The long-term objective is to promote better broadband infrastructure, adoption, and utilization in agricultural communities. Achieving these objectives would mean NC's rural agricultural areas would be connected via broadband and able to participate in the modern economy, receive health services, access educational opportunities, and many unconceived purposes.

In September 2021, NC State Extension's Broadband Access and Education Coordinator was named the National Broadband Fellow by the Extension Foundation and Extension Council on Policy (ECOP). The Fellowship is funded by NIFA's New Technologies for Ag Extension (NTAE) grant and supports the work of the National Digital Education Extension Team to build the capacity of Cooperative Extension Systems nationwide to address issues surrounding Broadband Access and Digital Skills Education. **This work is paving the way to ensuring that the lack of broadband access doesn't stand in the way of opportunities for our rural communities to thrive.**

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

The following professional development workshops were provided by Extension Specialists for Extension Agents in 2021 to facilitate the use and transfer of new research-based knowledge:

- Carbon Markets, Conservation Practices, and Ag Labor

- NC State Climate Office: Tools, Resources & Climate Communication
- COVID-19 Community Health Outreach to Vulnerable Populations
- Disaster Preparedness and Recovery Training
- Extension's Role in Disaster Management and Community Resilience
- Farm Machinery and Highway Safety
- It's Getting Hot Out There: Urban Tree Species & Climate Change
- Land Utilization & Heirs' Property: Standing on a Lot of Love
- Land Summit: Right to Farm, Bona Fide Farm, PUV, VADs, & Tenancy
- UAV Training for Ag Agents & Extension Professionals

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

Evidence of rural stress, broadband connectivity rates and utilization, and the number of communities needing upgraded infrastructure and services affect the state's ability to attract new businesses and residents. The COVID-19 pandemic tested community and government infrastructure at every level, creating unprecedented challenges associated with public health, food security, working conditions, and much more. NC State Extension utilized existing partnerships to distribute masks, hand sanitizer, and food to families in need during the pandemic. Extension was also able to leverage it's 101 local Extension Centers across the state to ensure the health and well-being of farmworkers and prevent significant disruption in agriculture production by leading vaccine distribution efforts. COVID-19 also reinforced the critical need to expand broadband access to rural portions of the state. Extension is part of efforts paving the way to ensure that the lack of broadband access doesn't stand in the way of opportunities for our rural communities to thrive.

Economic Development

Project Director
Meredith Weinstein
Organization
North Carolina State University
Accession Number
7000078

Building Local Economies and Helping Communities Become Attractive Places to Live, Work, and Play

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

The well-being of North Carolinians is determined in a large part by local economies. Vibrant local economies have an engaged workforce with a sense of opportunity, thriving downtowns with many local businesses, and high-quality economic development planning that builds on local assets. In NC, small downtowns are building local identities to attract new

businesses through placemaking and asset assessment. In the past 30+ years, over $2 billion has been invested in North Carolina communities to spur economic development through downtown revitalization. This investment has increased the number of new businesses and new jobs. Communities investing in their downtown districts have also seen increased community pride, a greater commitment to historic preservation, and greater support for locally owned businesses. However, there is much more work to do, especially in the rural portions of the state, which have experienced a loss in small businesses over the past two decades. NC is facing increasing economic, social, and environmental pressures. As the lifeblood of local economies, businesses and communities need expert guidance, education, and planning to thrive. NC community leaders and businesses also need to be empowered and educated to create more inclusive, equitable businesses, public services, and community engagement initiatives. In addition, there have been tremendous negative impacts on our local economies as a result of COVID-19 on the leisure, hospitality, and manufacturing sectors.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

To support workforce development, Extension provided education, guidance, and specialized training to entrepreneurs, Extension program staff and interns, and minority owned business. Extension conducted outreach to lay critical groundwork to strengthen NC's economy while fostering healthy, engaged communities in which individuals from all backgrounds can thrive.

Farm-City Week is a time of celebration and education about the wonderful benefits that agriculture brings to our lives each day. Alexander County Cooperative Extension typically celebrates and recognizes this special time with a banquet where rural and city leaders join forces to celebrate all things agriculture. However, with the pandemic still in the forefront, Alexander County Cooperative Extension instead chose to collect various items that represented various agricultural sectors to **make baskets that could be gifted to local county commissioners and town councilmembers**. Each item was paired with a tag describing the importance of that commodity to the county and the amount of revenue produced. Baskets included locally produced cornmeal, honey, a plant, goat milk lotion, a gift certificate to a blueberry farm, ground beef, blueberry jam, apple cider, and beeswax candles. **Social media posts** highlighting each industry were made to target a broader audience and highlight local agribusinesses. These items were presented to local dignitaries at their respective meetings. Extension shared recent agriculture-related census data and reiterated the importance of agriculture to Alexander County by way of revenue produced ($176 million) and jobs created. The social media posts garnered over 7,270 organic views. **Extension helped raise awareness of agriculture's profound impact on North Carolina's economy through innovative outreach.**

The Social and Economic Vitality Program of Wake County Cooperative Extension works to build an ecosystem of support for new or aspiring entrepreneurs in Southeast Raleigh and Eastern Wake County. The 10-week **Empowering Entrepreneurs and Seeding Innovation (EEASI)** program encourages new and aspiring adult entrepreneurs to develop an entrepreneurial mindset and recognize potential business opportunities. The latest EEASI cohort focused on increasing support to new and aspiring black entrepreneurs in Eastern Wake County. Nineteen graduates completed the program, with 11 participants going a step further to create and deliver pitches for a chance to win up to $3,000 to seed into their businesses. The participants represented various industries, including clothing, childcare, subscription services, media, social justice, counseling, and more. One of the winners plans to use the prize money to support the addition of a treehouse called "The Urban Tree," which will increase the amount of space for the children to engage, garden, camp, and explore. The entrepreneurs in the EEASI program are part of the continued efforts of Wake County Extension to **create a community of entrepreneurs who work together to help reshape opportunities in Southeast Raleigh and Eastern Wake County.**

A **workforce development program** provided college students with experience working within Cooperative Extension. Despite the challenges of the pandemic, 24 Extension interns from across NC, representing 28 colleges and universities, assisted Extension Agents and experienced a first-hand view of Extension careers, County Extension Center operations, and community engagement. Interns reported that they developed the career readiness competencies identified by the National Association of Colleges and Employers. When asked what knowledge, skills, and experiences they gained through the internship, they reported improved skills in workplace communications and professional relationship building, community leadership, maintaining a healthy work-life balance, working with people from diverse backgrounds, and adjusting professional plans to adapt to unexpected setbacks and changes. **Through internship experiences, college students are better prepared for the workforce and contributing to the local economy.**

Briefly describe how your target audience benefited from your project's activities.

2021 marked the fourth year of the **Vacationer Supported Agriculture** (VSA) program, which connects vacationers to fresh local food through an online ordering system. The total VSA sales for 2021 reached $91,397. This year's program included the expansion of the project to three additional counties and the addition of two new products as add-ons to the produce bags:

i.e., “happy hen eggs” and “Shrimpers’ catch.” Approximately 77.1% of the revenue was generated by the sale of produce bags, 5.6% of revenue accounted for sales of eggs, and 17.3% from the sale of shrimp. **NC State Extension efforts catalyze NC’s local economies to be attractive places to visit and play.**

A **small family farm** in upper Cleveland County sought to expand and improve sorghum syrup (molasses) production and explore the feasibility of producing heirloom grits and cornmeal for direct-to-consumer sales. They reached out to Cooperative Extension to help them navigate food safety regulations, investigate possible funding sources to construct an on-farm food manufacturing facility, and for advice on marketing their **value-added products**. Cooperative Extension helped the operators make connections with NCDA&CS Food & Drug Protection Division personnel to determine food safety regulations for food manufacturing facilities. They also received guidance in applying for grant funding through the Western North Carolina AgOptions program, consultation regarding marketing their value-added food products, and advice on positioning their farm as an agritourism destination. The farm received funds to construct a sorghum processing facility that passed a food safety inspection. They used the facility to process 135 gallons of molasses in 2021. Test marketing of their grits and cornmeal convinced them to become a new vendor at Foothills Farmers' Market in Shelby, where they have developed a strong and loyal customer base. They purchased and restored a 1935 farmhouse on adjoining property and are generating additional income by operating it as an Airbnb. The operators now have plans to improve their milling operation and expand the production of their corn products. **NC State Extension helps grow small businesses and enhance local economies.**

After losing much of their viniferous grape crop, a local vineyard wanted to replant a more reliable cultivar ('Carlos') of rotundifolia grapevines. The vineyard needed the grapes from this section of their vineyard to help supply the wine demands of their winery. The vineyard is an ag tourism/event venue, and the vines add to the atmosphere of the venue. To accomplish this task, they turned to Cooperative Extension for assistance. The horticulture agent in Person County worked with the vineyard in completing a grant application. By working with the Extension agent, they developed a strong grant application and were awarded funding that allowed them to replant the vines they needed for future grape production. **This service not only helps the vineyard with their wine production but also provides NC residents an opportunity to visit an agricultural venue and observe grapevines growing while contributing to the economy of Person County.**

To support economic development in NC’s retail, accommodation, entertainment, and tourism sectors, Extension has implemented the **Create Bridges** process, a strategic planning initiative currently being piloted in 6 states to address challenges associated with sector-specific planning and workforce training that is often neglected or underemphasized despite a need to strengthen it. Because of NC’s dependency on the tourism sector, the Mountain West Region (Jackson, Swain, Graham, Macon Counties, and the Qualla Boundary) was selected to test the impact and effectiveness of this 2 ½ year planning process to identify the region’s strengths, challenges, and opportunities. The major challenge identified by businesses was the lack of qualified workers and the surveyed employees reported that only 54% feel valued by their employers. **The region is working now on strategy development, including how to be a better employer by offering cross-training and entrepreneurial skill-building programs for their employees.**

Briefly describe how the broader public benefited from your project's activities.

During the COVID shutdown, Extension in Currituck County led a facilitation effort to initiate the **African American Experience of Northeast North Carolina (AAENENC)**. The mission of this 6-county group is to inspire exploration and appreciation for the African American experience in Northeastern North Carolina and ultimately drive cultural tourism and economic benefit for the region. Phase one of the project included building a solid team of advisors and history advocates; creating a workflow, collaboration, and team spirit across 6 counties; establishing a mission and vision; locally showcasing African American history; obtaining a URL for the effort and engaging a black-owned business to build out the site; launching a social campaign and establishing a collaborative marketing strategy. Completion of phase 1 occurred on Juneteenth, 2020. Following the success of the initial effort, Currituck County Cooperative Extension re-engaged to facilitate Phase 2, in which a 3–5 year plan to guide the work of the group was completed and shared with the advisors. Short-term action plans were also delivered, and committees have begun the work. Several members of the team expressed that the initiative would have stalled long ago were it not for the guidance of Extension and the assistance with group process facilitation. Because of the success of this regional initiative, state leaders in NC tourism have approached Currituck County Extension for guidance on expanding the program to other regions of the state. **To increase local tourism by facilitating local planning groups to develop and implement missions, visions, and strategic plans, NC State Extension supports local economic development efforts**.

Cooperative Extension was contacted by the Pamlico County Manager to participate in an action committee to address concerns of citizens and townships about the growing presence of **roadside litter**. Citizens were troubled about the negative economic and environmental effects that unsightly litter was contributing to local businesses and communities. Roadside litter remains an ever-present problem across all of North Carolina, with the North Carolina Department of Transportation reporting spending more than $11 million to remove litter from NC roadways during 2020. To address these concerns, committee members agreed that both education and action were needed. As a result of this program, more than 200 tarps

were distributed to citizens to prevent roadside litter loss during transport, and more than 100 volunteers took part in collecting over 300 bags of roadside litter. **Through these efforts, approximately 3,000 pounds of roadside litter were removed from the roadside of Pamlico County, helping to improve the aesthetic value and environmental and economic impacts on our local communities and businesses.**

The farming communities of Rutherford and Polk counties have been moving toward **small agritourism events** as a way to create additional revenue streams and for marketing purposes. In 2021 Extension's farm tour was split into small gatherings that were only advertised to local people through Facebook and email newsletters. The 5 events were held throughout the summer and fall seasons, with 2 farms participating each day, for a total of 10 farms participating across the 2 counties. The farms were highlighted when their products were at their peak. Customers were able to forge relationships with the farmers while learning about their local agricultural system and production methods. The farmers were able to sell products and encourage participants to engage with their sales outlets once the event was over as well. Feedback from participants was overwhelmingly positive, as they enjoyed getting to know their local farmers and hearing about their reasons for how and why they produce their goods in the way that they do. Farmers also enjoyed the smaller groups and more intensive farm tour style, and many of them are holding similar events on their own now as well. **Through Extension sponsored agritourism events, local farms can generate additional income streams while educating the public about food and farming.**

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

The following professional development workshops were provided by Extension Specialists for Extension Agents in 2021 to facilitate the use and transfer of new research-based knowledge:

- Agritourism Curriculum: Western NC Success
- Ag Labor in NC: Challenges and Opportunities
- A Roadmap from Raw Ingredients to Value-Added Food Products
- Creating a game plan to develop entrepreneurial farmers
- Drone Videography Tips
- Farm School Online Course

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

The well-being of North Carolinians is determined in a large part by local economies. Vibrant local economies have an engaged workforce with a sense of opportunity, thriving downtowns with many local businesses, and high-quality economic development planning that builds on local assets. To support workforce development, NC State Extension provided education, guidance, and specialized training to entrepreneurs, program staff and interns, and minority owned business. Extension conducted outreach to lay critical groundwork to strengthen NC's economy while fostering healthy, engaged communities in which individuals from all backgrounds thrive.

Families and Communities

Project Director
Meredith Weinstein
Organization
North Carolina State University
Accession Number
7000172

Use of Effective Parenting, Caregiving and Life Skills to Create Stable, Safe and Secure Environments

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Individuals and families in North Carolina face challenges to overall well-being. The state's population includes over 2.3 million children under age 18. Many young children's social, emotional, or mental well-being has been impacted by the pandemic. At the other end of the spectrum, North Carolina ranks 9th nationally in the number of people 65 and over. In 2019, the state had more people 60 and over than under 18. Elderly populations have faced disproportionately high rates of illness and death from COVID-19, and many experienced new levels of isolation, which exacerbated existing health problems and led to increased fear and emotional suffering.

The well-being of families is also impacted by where they live. Approximately two-thirds of American families live in a home with at least one health hazard. Further, 10.6% of housing in NC has the potential for elevated lead exposure risk. Radon exposure, the leading cause of lung cancer among non-smokers and the 2nd leading cause of cancer among all individuals, have elevated levels across the state. Home hazards are also a concern, as 24.8% of adults aged 65 and older reported falling in 2017. About $50 billion is spent annually on medical costs related to non-fatal fall injuries, and $754 million is spent related to fatal falls. Families spent more time in their homes because of COVID-19 and had more frequent exposure to these household risks.

Many families are also facing what seem like insurmountable financial challenges. Between the amount owed on student loans, home mortgages, and credit card debt, in 2020 Americans carried a record $14.9 trillion of debt, surpassing the 2010 levels following the Great Recession. The average total consumer debt in North Carolina was $84,343 in November 2020. The COVID-19 pandemic has brought financial hardships to North Carolinians, who added nearly $1.5 billion more credit card debt in 2021. The state now ranks 9th in total outstanding consumer credit card debt, with $30.4 billion outstanding. The average household debt due to consumer credit cards is $8,158, and the average student loan borrower carries a debt of $36,257. At the height of the pandemic, Wake County's Housing Department reported that upwards of 700 families faced eviction each week.

NC State Extension needs to empower individuals and families to build healthy lives and achieve optimal social and economic well-being.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

To support individuals and families, NC State Extension Specialists developed and delivered in-service training, educational curricula, and materials to increase the knowledge and skills of Extension Agents thus increasing their ability to deliver subject matter content to target populations. Extension Specialists and Agents delivered educational content using programs, websites, social media, newsletters, and other methods to increase the knowledge and skills of the target populations.

- NC State Extension Agents used **social media and mass media** to provide educational information to individuals and families. Agents had a social media reach of 334,919 and a mass media reach of 7,366,129.

- NC State Extension Specialists maintain 2 **web portals** containing 255 individual web pages providing information on Families & Communities and Healthy Homes. 8 new web pages were added in 2021 along with new educational content added to 13 existing pages. The families and communities' websites maintained by Extension Specialists were viewed 208,071 times.

- Extension Agents delivered **in-person and virtual training** to 2,499 individuals on wellness, 649 individuals on budgeting/managing financial resources, 555 caregivers on parenting, and 245 individuals on healthy homes.

Extension in Durham County offered the **Positive Parenting Program®**, a parent and family support system designed to prevent and treat behavioral and emotional problems in children and teenagers. Over 28 Spanish-speaking parents and caregivers shared their experiences with the ups and downs of the pandemic while discussing topics such as stress, daily chores, supporting healthy relationships, and managing disagreements, as well as tips for school life. Families were appreciative and welcomed local and online resources that were shared during these virtual workshops.

Caregivers of ill relatives, as well as guardians raising children, take less time for self-care, as finding time to maintain basic levels of physical and mental health can be difficult. Cooperative Extension offered twenty **virtual classes** on stress management, nutrition information, communication topics, and parenting resources for caregivers. **Extension provided resources to help parents and guardians promote healthy relationships, utilize positive parenting practices, and manage stress.**

To help families be prepared for the increase in natural disasters and unprecedented events, NC State's More in My Basket (MIMB) team developed the **Versatile Pantry** session. Participants learned about the benefits of stocking a few pantry staples, strategies for creating a stocked pantry, versatile methods of pantry storage and organization, how to keep track of food in the pantry, and a variety of meals that can be prepared from a set of staple ingredients. MIMB staff developed a PowerPoint, recipe cards, leader's guide, pre and post-session evaluation forms, and various handouts to aid in agent delivery of the Versatile Pantry session, as well as a Versatile Pantry Guide for participants. **Extension improved the quality of life and well-being of consumers by teaching principles of disaster preparedness.**

The Pasquotank County Cooperative Extension staff worked together to assist senior citizens with **choosing prescription drug plans**. In 2021, counseling sessions were conducted primarily by phone to protect the vulnerable senior population who were at high risk of contracting COVID-19. Washington County Cooperative Extension, through the Senior Health Insurance Program, worked closely with seniors to help them make wise financial decisions about their Medicare Part D coverage. **NC State Extension improved individual and family financial stability by teaching older residents strategies that support economic security.**

Families across North Carolina experienced an increase in the cost of food used to cook traditional holiday meals. In 2021, COVID-19 introduced several disruptions to the food supply chain: rising food costs, food shortages, and uneven food availability in grocery stores. These conditions compounded the normal additional expense of preparing a holiday meal and underscore the importance of advanced planning and early action. A 6-part series, **Getting Ahead of the Holiday Meal Cost**, was developed to provide a just-in-time guide to encourage early, sequenced purchases of food ingredients and related preparation for upcoming holiday meals. The series allowed each participant to tailor their experience by using their favorite holiday recipes as the basis for planning throughout the series. Eat Smart Move More North Carolina adopted the program as part of its Holiday Challenge, sharing the series with its 45,000 program participants. In total, the Getting Ahead of the Holiday Meal Cost program reached 235,325 individuals. **Extension's research-based programs provide solutions and empower clients to make better-informed decisions**.

Briefly describe how your target audience benefited from your project's activities.

Cooperative Extension in Currituck County provided a series of self-care and mental health programs, including a self-care challenge, a mental health pop-up seminar series, and a yoga challenge. As a result of these activities held throughout the year, 101 participants were able to access information that helped them develop life skills including goal setting, improving physical fitness, improving diet, and practicing mindfulness and gratitude. Of those who completed the evaluation, 85% stated they learned new ways to cope with stress, and 72% will continue to practice mindfulness and gratitude. **After attending Extension self-care programs, participants can use new strategies to cope with stress; practice self-care, mindfulness, and gratitude; and lead lives that balance physical, mental, and emotional health.**

Kinship care refers to relatives, or in some cases close family friends, caring for children in foster care. Kinship care families were impacted in different ways during COVID-19. Cooperative Extension in Cleveland County conducted limited in-person and/or virtual support group sessions (depending on COVID conditions). In-person meetings were held in outdoor settings and/or scheduled for 3-4 families at a time. Educational enrichment and community resource information were shared at each meeting and through electronic newsletters. **The Grandparents Raising Grandchildren (GRG) & Kinship Care Support Group** remained an important resource to the kinship care families. Families reported that the support group met its goals and the needs of the families and has helped families know they are not alone and that other kinship caregivers and children are living in the community. The participating adults and children made new friends; feel supported and acquired new skills for communicating with family members, advocating for their children, and reaching out to access new community resources. Support group programming also helped families learn new parenting skills and ways to strengthen their families. All the

grandparents indicated they did not have support before their involvement with the support group and they would recommend the support group to other kinship caregivers. **North Carolina caregivers at all stages of life use effective parenting skills to create stable, safe, and secure environments by participating in NC State's Extension programs.**

Falls are the leading cause of fatal and nonfatal injury for older Americans, with 1 in 4 Americans aged 65+ suffering a fall every year. In partnership with the Centralina Area Agency on Aging, Cooperative Extension's Gaston County Center conducted 3 **Matter of Balance** workshops for residents in 9 area counties. The 25 participants adopted behaviors to reduce their risk of falling. Participants reported increasing physical activity by doing strengthening, flexibility, and balance exercises at home. Several participants reported making home modifications (i.e., improving light, removing area rugs, and adding grab bars to bathrooms). One participant reported that, based on what was learned in the workshop, she was able to correctly assist an older adult who had fallen in her apartment complex. She asked the fallen individual to do a self-assessment before moving and to report the fall to a healthcare provider. Participants of the Matter of Balance workshop were also referred to Extension's newest physical activity program, **LIFT (Lifelong Improvements Through Fitness Together)**. Washington County Cooperative Extension partnered with the local Senior Center to offer **LIFT** to older adults to improve balance and flexibility and help prevent falls.

Catawba County has a growing retirement community. Currently, the county emergency medical services report that 1 out of 3 emergency room visits is the result of someone over the age of 65 falling. With regular practice, Tai Chi improves balance by strengthening muscles and coordination; at the same time, it strengthens the mind, thereby improving calmness and confidence in not falling. **Tai Chi for Fall Prevention** was offered a total of 4 times a week by Cooperative Extension at both YMCAs in Catawba County as well as online, and **Tai Chi and Hike**, a collaboration between Extension and Catawba County Library and the Catawba County Park System, was offered monthly. Ninety-eight percent of participants report that the classes have improved their balance. Ninety-three percent say that the classes have helped them reduce stress and be more active. Sixty-five percent reported that the program motivated them to visit county parks. **Extension improved quality of life and well-being for consumers by teaching principles of fall prevention.**

Radon is a naturally occurring radioactive gas produced by the normal breakdown of uranium in rocks, building materials, and soil. As radon breaks down, it produces radioactive particles that, when breathed in, become lodged in the lungs. Testing is the only way to determine radon levels in a home. To protect homeowners from the hazards of radon, NC State Extension partnered with the NC Radon Program to offer radon continuing education for real estate professionals and early childhood care providers. In all, six 4-hour sessions were conducted for real estate professionals and three 2-hour sessions were conducted for childcare providers. Nearly 60% (59.3%) indicated that they would test their facility for radon. If needed, just over 18% indicated that they would install a radon mitigation system. The real estate professionals that participated in the **Radon in Real Estate** Course reported having a better understanding of how radon exposure is a risk factor for lung cancer (97%), feeling more confident in their ability to educate clients about radon during the home buying/selling process (98%), and providing more radon resources to clients since completing the course (87%). **This program results in an increased number of homes in NC being tested for radon and mitigated radon exposure utilizing accredited standards, as well as the fulfillment of NC Cancer Control Plan strategies.**

Front line staff often find themselves dealing with emergency situations but don't feel comfortable providing care until emergency personnel arrives. **CPR and First Aid Certification Training** was provided by a Family and Consumer Sciences Agent throughout the year to hotel, preschool, and church staff members. The training provided these workers with a necessary level of comfort in dealing with emergencies by knowing the best care to provide in a variety of situations and providing them with the confidence to provide help until medical assistance arrives. Two hundred and twelve participants were certified, with 31 more participants who were trained and did not desire certification. All the participants shared that they felt more confident after the training knowing what they should and could do to help someone in need in their location. They also said they appreciated that they could use the skills not only at work but at home or anywhere. The participants know there might come a time when they need to help someone. **They now have the knowledge and skills to provide life-saving assistance and the confidence of knowing they are doing all they can until the professionals arrive.**

Briefly describe how the broader public benefited from your project's activities.

In January of 2020, Durham's Board of County Commissioners approved an 18-month contract with the Durham Children's Initiative (DCI) to facilitate a community planning process to develop an **Early Childhood Action Plan (ECAP) for Durham County**. Despite the pandemic, Durham County Cooperative Extension staff, the Durham Children's Initiative, and over 150 community members worked together to develop recommendations about how to make things better for Durham families with young children. Parents, front-line workers, community-rooted leaders, nonprofit and systems leaders with lived experience and expertise across maternal and child health, early care and education, and family support systems came together, built relationships, and shared their experiences. The plan was informed by the voices of over 1,000 parents and early childhood care providers.

Durham County's Early Childhood Action Plan has been finalized and released, and a representative, 36-member steering committee is made up of parents of young children, front-line workers in early childhood fields, community-rooted leaders, and nonprofit and institutional leaders have been established and are meeting monthly. To address the persistent disparities in early childhood outcomes in Durham, the plan focuses on the following goals: valuing the voices and experiences of families in the community; addressing root causes like poverty and racism to prevent acute stress and trauma for families; ensuring there is a set of universal, family, and child-focused supports that promote thriving for all; ensuring there is a set of culturally-affirming, anti-racist, affordable supports that address family stress and trauma; changing harmful mental models that prevent systems from changing in necessary ways; and building intentional collaboration across different parts of the system so that the entire system is stronger. Stakeholders have begun presenting the plan to county staff, external stakeholders, and funders, and the plan has already been leveraged to bring in significant grant funding for aligned strategies. **Extension collaborates with community partners to address the root causes of problems facing families with young children.**

As a result of the successful planning process that took place to create Durham's Early Childhood Action Plan, Duke Pediatrics, the medical home for a large number of Medicaid-eligible children in Durham, reached out to Extension and the manager of the Early Childhood Action Plan (ECAP) with a request to partner on a grant opportunity. The opportunity aligned with the pediatric and social-emotional health strategies in the Early Childhood Action Plan. The goal of the project is to transform pediatric care to strengthen parent/child relationships and family social-emotional health. Funding will support both evidence-based and community-rooted supports for families with children 0–3 years of age, as well as system and practice changes at Duke Pediatrics. Perhaps most importantly, the project begins with a community co-design process, in which the parents of young children at Duke Peds and community-rooted organizations working in maternal and child health will be partners and decision-makers in determining how the funds are allocated. **NC State Extension works as a catalyst to engage community members as active participants and leaders in making decisions that impact their communities.**

To build a foundation for financial well-being later in life, Cooperative Extension provides programs teaching youth financial literacy skills. Middle school students in Bertie County participated in the summer enrichment program **Money Smart**. The 35 middle-grade students enrolled in the Money Smart Curriculum learned about topics such as the path to success, earning, spending, saving, borrowing, and protecting. Eighty percent (80%) of the participants improved their knowledge about budgeting, savings, and keeping their identity safe. Hyde County 9th and 10th graders were introduced to the basics of **financial literacy**. Topics included SMART goals, how goals and values impact the use of financial resources, tracking spending, the importance of checking credit, and how to respond if there is inaccurate information. Students improved in their understanding of SMART goals. Most students increased their understanding of which types of expenses are considered fixed and flexible, why it is helpful to track spending habits, and important information needed for creating a spending plan (or budget). Additionally, all students learned where and how to check their credit from safe and reliable resources and learned why it is important to check their credit. Extension 4-H school programs provide youth with skills to reach their full potential, so they contribute to thriving communities

To support the financial literacy of seniors struggling with increasing medical expenses and complex Medicare plans, the **Seniors' Health Insurance Information Program (SHIIP)** teams in Pasquotank, Currituck, Chowan, Washington, and Surry Counties counseled over 1,812 seniors, helping them save a total of over $1,244,000 in prescription drug costs and insurance premiums. SHIIP provides local, in-depth, and objective insurance counseling and assistance to Medicare-eligible individuals, their families, and caregivers. Cooperative Extension also partnered with the state SHIIP program and local partners to raise funding to bring the **NC MedAssist Drug Giveaway** program to Tyrrell County. Over 50 volunteers marketed the event and handled logistics. As a result of the MedAssist Drug Giveaway, 748 people were served in 1 day with medicine bags valued at $50 each. An additional 252 medicine bags were distributed through Meals on Wheels to the homeless and isolated individuals. **NC State Extension's technical assistance empowered seniors to make better-informed decisions, resulting in a healthier North Carolina.**

At the height of the Pandemic, Wake County's Housing Department reported that upwards of 700 families faced eviction each week. Although federal relief housing resources were allocated to the county, there were months when 9,000 families were waiting to have their applications processed. Wake County Cooperative Extension hosted a community-driven **Eviction Clinic**. During the event, staff and volunteers assisted residents with completing House Wake Applications. Attendees received legal information to prevent eviction. One hundred and twenty-five residents attended the clinic, many of whom were grateful to have one-on-one application support and someone to listen to their concerns. In addition to application completions and receiving legal consultation, residents received economic mobility resources, information on civic engagement opportunities, and took home household goods and snack bags.

As a result of Extension programming to improve individual and family financial stability: 4,123 people gained knowledge to increase family economic security (such as how to access SNAP benefits, SHIIP Medicare Part D, food cost management, and cost comparison skills); 2,695 people accessed programs and implement strategies to support family economic well-being; 683 people gained basic financial management knowledge (such as budgeting and record-keeping); 340 people gained

knowledge to increase family assets (such as home ownership, estate planning, savings and investments, and retirement planning); and 219 gained knowledge in managing financial products and financial identity (such as credit/debt management, identify theft, credit scores, and avoiding scams). **The increase in individual knowledge gained from participation in Extension's financial management and support programs not only leads to an improvement in the financial condition of the individual participant but results in a ripple effect felt throughout the economy.**

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

The following professional development workshops were provided by Extension Specialists for Extension Agents in 2021 to facilitate the use and transfer of new research-based knowledge:

- Healthy Homes
- Household Cleanup after a Disaster
- Identifying and Helping Clients with Delusory Parasitosis
- Making Wood Furniture Last
- Mold 101e- Prevention and Clean-Up Training
- More In My Basket Training
- Radon Education for Child Care Providers
- Supporting Breastfeeding for the Community

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

Individuals and families in North Carolina face challenges to overall well-being. To support individuals and families, NC State Extension developed and used educational programs, websites, social media, newsletters, and other methods to increase the knowledge and skills of individuals and families. As a result of Extension programs, more North Carolinians use new strategies to cope with stress; practice self-care, mindfulness, and gratitude; and lead lives that balance physical, mental, and emotional health. North Carolina caregivers at all stages of life are now using effective parenting skills to create stable, safe, and secure environments because of participating in NC State's Extension programs. The knowledge gained from NC State Extension's workshops and technical assistance on financial management not only led to an improvement in the financial condition of the individual participants but resulted in a ripple effect felt throughout the economy.

Family and Consumer Sciences

Project Director

Lauren Hargrave

Organization
North Carolina Agricultural and Technical State University
Accession Number
7001842

Financial Literacy & Management

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

According to the National Low-Income Housing Coalition, North Carolina's low and extremely low-income residents cannot afford to spend 30% of their income on housing. Residents who use more than 50% of their income to cover their housing are left with 50% or less to support other expenses such as food, medical care, transportation, childcare, etc. The Financial Industry Regulatory Authority (FINRA) found that many Americans who maintained more than $100 in savings were much less likely to have utilities shut off or resort to high-interest borrowing measures. Providing low-income residents with the skills to set goals, budget, and save through budgeting and credit programs will better prepare them for emergencies. Additionally, many high school students graduate with little or no knowledge or skills in personal finances and economics, resulting in high consumer debt such as credit card debt, bankruptcies, and student loan debt. This contributes to the high consumer debt rate and high rate of student loan defaults.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

For all financial literacy and management programs in the counties, a total of 333 participants attended 25 workshops covering more than 15 hours.

For the “Real Money, Real World” program, simulations for middle and high school students were completed by volunteers and school staff. Students were given a scenario and had to operate the simulation as if they were living as an adult to see if they would have money at the end of the simulation. There was a total of three simulations conducted in 2021.

Agents used several publications, including the H-Plan and PowerPay debt reduction tool, to help participants determine income, spending, debt levels, and learn about debt reduction.

During the NC A&T faculty and staff institute, the Family Resource Management (FRM) coordinator trained 15 agents on the H-Plan, which teaches adults how to budget. The FRM coordinator also provided professional development to 11 participants for the “Your Money Your Goals” program. There were six additional one-hour professional development and information sessions on finance and budgeting provided to 324 participants by the FRM coordinator.

Briefly describe how your target audience benefited from your project's activities.

The Scotland County Family and Consumer Sciences (FCS) agent collaborated with the Scotland County Re-Entry Program to offer a three-part workshop on financial management. Topics included: Why Do I Need a Financial Plan?; Understanding Financial Terminology; How Do I Develop a Financial Plan?; and H- Plan– How Much, How Well and How to Manage My Money. In addition, the workshops covered how to obtain a free credit report from the three reporting agencies, understanding credit and credit scores, the importance of saving, PowerPay, and banking 101 information. After the workshop, 100% of the participants said they gained new knowledge about taking control of their financial health. All the participants shared they planned to with obtain their credit report to determine their credit score and identify any issues that need to be resolved. In addition, establishing a bank account and saving a portion of their pay was a priority.

Harnett County's Community and Rural Development (CRD) agent, in partnership with a local non-profit, provided volunteer hours to offer free tax assistance that benefits more than the taxpayers served by the program. The effort has public value to all taxpayers because federal and state refunds stabilize the county tax base, stimulate the local economy, and reduce demand for public assistance by helping taxpayers easily gain access to their refunds. In 2021, over 1,000 participants received free tax services, which saved them an average of $120 per household, totaling approximately $120,000 in savings. This service provided a way for us to fill a need and offer county residents education on ways to increase their refund by saving and planning. As a result, a continued partnership for the 2021 tax season has been established and training began in January 2022. Refunds and the tax preparation fee savings mean more financial resources that individuals and families can use to meet their financial goals and achieve a better quality of life.

The Guilford County FCS agent partnered with the Title I middle school family and consumer sciences teachers at Guilford County Schools to create a program centered around budgeting and saving for middle school students. During this series, students learned the fundamental tools needed to be knowledgeable and successful with budgeting and saving their money at an early age. One teacher wanted to create more of a challenge for her students, so we discussed starting a savings challenge. This challenge was created three years ago, and with the combination of information learned during the 2021 series and what was applied in class, students continue to increase their saving efforts. As a result, this teacher's students saved more than $1500 over the last three years. Students were excited about their accomplishments and stated that they would start a savings account with a local bank. This class and the self-investing project have been successful for the students and will continue year after year. Two other middle schools have also adopted this idea.

The Montgomery County FCS Agent partnered with Communities in Schools of North Carolina to implement the "Real Money, Real World" spending simulation at the county's high school. The FCS and 4-H agents partnered to recruit 27 community volunteers to serve in various booths. One hundred twenty-seven seniors participated in the event and were assigned a specific career, salary, and family size. Participants then had to visit 14 booths and make spending decisions related to monthly expenses (e.g., transportation, food, childcare, housing, insurance, etc.). The successful and eye-opening experience taught seniors just how important it is to save money, achieve higher education, and wait until they are financially ready before having children. A total of 89% of seniors were surprised at how much it costs to have a child, and 85% said the experience helped them learn how important it is to make wise financial decisions. Seventy-six percent said they intended to open and maintain a savings account, and start saving now. Over 60% of participants stated they would think about how their spending impacts their opportunities and others in their lives. They also said they plan to seek out more training or education after high school and develop a money plan for their wants and needs. Approximately 90% of the participants stated it is very likely that participating in the program will help them in the future. Additionally, the students increased their knowledge from a little to a lot in realizing the cost of caring for a child, knowing how to ask questions before making a purchase, making wise financial decisions, understanding paycheck deductions, and knowing the importance of a saving and spending plan. Volunteers overheard many comments by students about the program's impact on their lives. One volunteer shared how one student looked at her professionally done fingernails and asked how many diapers could be purchased with the money she usually spent at the salon. This is evidence that students are learning to determine the difference between needs and wants.

The Montgomery County FCS Agent partnered with the 4-H agent to hold an "Adulting 101" program as part of the 4-H Summer Adventures series. During this three-day workshop, 13 youth learned the importance of saving, developing and monitoring a personal budget, and choosing and using credit wisely. Education included healthy meal preparation and planning on a budget. Additionally, youth learned life skills such as doing laundry and performing essential car maintenance. Youth learned basic interviewing skills and resume building and were introduced to college financial aid. Youth also focused on improving their communication skills and building and maintaining healthy relationships. Pre-and-post-tests indicated a 20 point increase in knowledge. Participants demonstrated improvements in their abilities to separate needs from wants, compare prices before making purchases, be involved in community service, serve as a leader, and save money for the future. Participants also demonstrated improvements in their ability to understand non-verbal communication cues and communicate more effectively with others. Many youths commented that they learned the importance of putting money in a bank account and intentionally saving at least $20 per month. One young man who participated went home shared the information he learned with his parents and even made his own Facebook live video to share his knowledge with the public. All participants reported feeling more ready for adulthood and indicated that they would encourage their friends to take the class. Participants all agreed that they learned a lot about time management and how important it is "to get the most important stuff done first and then trickle in time to goof off."

Briefly describe how the broader public benefited from your project's activities.

N/A

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

N/A

Local Food Systems
Project Director
Meredith Weinstein
Organization
North Carolina State University
Accession Number
7000173

Resilient Local Food Systems that Promote Food that is Grown, Caught, and Raised within North Carolina

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Consumer demand for local foods contributes to the creation of jobs and opportunities throughout North Carolina for our farmers, businesses owners, and entrepreneurs that store, process, market, and distribute locally produced foods. As markets for local foods grow, so do opportunities for farms and local food businesses. Resilient localized food systems ensure a continual supply of safe, accessible food for all community members while supporting the economic vitality of farmers of all scales. There has been a renewed spirit for customers to purchase food locally and support local farms. Food shortages during the COVID-19 pandemic further emphasized the need to purchase foods locally. But the pandemic also brought unprecedented challenges to the in-person marketing efforts growers often use to engage with consumers, such as farm tours, fairs, and farmers markets.

Research shows that direct-to-consumer markets are important market channels for new and beginning farmers to build a customer base to build their business. Many of North Carolina's 20,298 new and beginning farmers lack prior agriculture experience, but growing support for local foods and sustainability has driven the interest of a diverse group of young people to go into farming and associated food businesses. Small farmers can meet consumer demands, but they need training and education to achieve this.

Engagement with local food systems increases grower profits and supports our agricultural economy and provides critical education and awareness to the public regarding the importance of agriculture. Educating consumers about the importance and significance of agriculture is a major concern in North Carolina. Soaring populations in North Carolina and rapidly accelerating development in rural areas have led to alarming increases in farmland loss.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

A growing number of farms provide direct-to-consumer sales in their local communities through farmers markets, CSA programs, farm stands, and other channels. The shorter the distance between the farmer's field and the customer's plate, the less transportation and fewer intermediaries required. This benefits both the farmer in keeping a greater percentage of their sales and the consumer in purchasing fresher food. As an added benefit, the money spent in the community stays in the community, supporting other businesses that offer goods and services and creating jobs. Agricultural lands have been irrevocably lost in recent decades due to residential and commercial development. **NC State Extension Agents and Specialists work with local communities to provide education and advocacy, preserve fertile agricultural lands in North Carolina that feed us and provide a host of economic, environmental, and socio-cultural benefits.**

By using **Donation Stations,** Extension Master Food Volunteers (EMFV) and Farmer Foodshare volunteers manned tables at farmers markets where farmers and shoppers could donate local food to people in need. Food was then shared with local agencies serving neighbors in need. Extension developed a resource guide and kits to help Extension Agents start a Donation Station in their county and report volunteer hours and pounds of produce collected for donation. **Cooperative Extension increased access to locally produced food through food assistance collection and distribution programs.**

NC State Extension created 12 **Local Food Posters** that feature a local fruit or vegetable that is in-season that month. Each poster contains nutrition information, local food facts related to NC agriculture, and low-cost recipe ideas. Posters were shared with Extension Agents for distribution; 92 food pantries across the state displayed the posters. **Local food demand was increased through partnerships and programs aimed at increasing the community's knowledge of and access to local foods.**

Farm-to-School programming has been unfolding in North Carolina for a long time in various ways. County Cooperative Extension Centers have been teaching kids about agriculture and cooking through **school programs, camps, and field days**. Agents supported farmers in finding new markets and meeting those market demands. Through **training, fact sheets, and programs**, NC State Extension's Farm-to-School Work Group increased Extension's capacity to support farm-to-school efforts

across the state. The Extension Farm-to-Early Care and Education (ECE) workgroup created a **resource guide** for Extension Agents that shows how Farm to ECE programs serve families and provides ideas for potential efforts. Another goal of the guide was to enhance partnerships among ECE and food system entities within communities so Extension may better serve farmers and families. **NC State Extension developed and delivered research-based training and resources to increase the capacity of Extension Agents, farms, schools, and childcare providers to grow farm-to-school programs.**

Briefly describe how your target audience benefited from your project's activities.

Extension in Davie County worked with local farms and agribusinesses to establish an online directory of local farms that sell products directly to consumers. A webpage was created that separated the farms into various categories, such as fruits and vegetables, meats and poultry, honey and honeybees, agribusinesses, etc. The directory included contact and product information as well as links to social media pages and/or websites. In 18 months, the online directory received almost 2,200 visits. The directory has proven to be an accessible, free marketing tool for Davie farmers and a resource for the community to find locally grown foods.

NC State Extension's NC Choices program expanded the MeatSuite.com platform, to provide a direct-to-consumer directory for bulk meat sales. The platform has over 170 farm users, and the marketing team has increased its social media presence and developed targeted promotions to direct buyers. **Extension helped agribusinesses take advantage of low-cost marketing opportunities that keep pace with rapidly evolving technology.**

Johnston County is the fastest-growing county in NC. As a result of the influx of new residents, farmland in the county is quickly being purchased by developers, leaving farmers to balance high land prices and preservation of their operations. As new homes are erected next to working farms, new residents are often disconnected from agriculture, farm practices, and food production, leaving them with many questions and concerns. The Johnston County Cooperative Extension Center, in partnership with the Johnston County Visitors Bureau, began a marketing initiative known as "JoCo Grows Agriculture" to connect consumers to local farms, driving traffic to purchase local foods and products directly from farms and encouraging them to engage in dialogue with farmers. A website, social media accounts, and the NC Farms App have been showcased to connect Johnston County residents to farms in their community. In 2021 alone, over 20,000 people received information regarding seasonality, production and harvest practices, local food information, and recipes promoting local food and agriculture in Johnston County through social educational videos. This effort was complemented by Extension workshops, such as food preservation and cooking classes, to increase skills and confidence in utilizing local foods as part of nutritious meals. Extension agents hosted demonstrations to provide consumers purchasing local fruit and nut trees with skills needed for proper care of these plants for years to come. In addition to reaching the community through social media and in-person events, billboards were placed alongside high-traffic roadways in Johnston County, with approximately 6.6 million cars, conservatively, viewing these billboards since September of 2021. **With Extension's help, local agribusinesses are continuing to increase direct consumer spending at farms, narrowing the disconnect between consumers and the agriculture community.**

New and beginning farmers in the Northern Piedmont of North Carolina often lack the financial and marketing training needed to put together a formal farm business plan. Completing **NC Farm School** equips farmers with the knowledge to analyze their business enterprises, set pricing, budget their time and resources, and make more informed decisions about what products work best in their farming businesses. As part of NC Farm School, 4 farm visit days were organized, and the participants visited 2 farms on each day. The farm visits allowed the NC Farm School participants to hear from seasoned farmers about how they got started and how they make decisions on their farms. As a result of the 2021 Northern Piedmont farm school, 28 farmers were introduced to the AgPlan business planning software and the program material. Twenty-four completed the program class sessions, field days, and one-on-one farm visits. Among those 24 participants who completed the classes, 15 farmers received their graduate certificate, which meant they had a complete farm business plan and had completed 80% of the classwork assigned. These farmers are now equipped with a business plan they can use to secure financing and use as their roadmap to build a successful farming enterprise. **Extension fueled the continuous growth of robust local food systems by providing training, education, and guidance to new and beginning farmers.**

In 2020, Extension formed the Henderson County **Farmers Market Coalition** with market managers, health department leaders, and community non-profits to build a core group dedicated to promoting and improving equal access to locally grown and produced food. Since the formation of the Henderson County Farmers Market Coalition, two new markets have opened in the county, one of which is in a USDA-identified food desert. As a result, food access has increased in two previously underserved areas. The Henderson County Farmers Market Coalition has not only increased food access and affordability of local produce to numerous citizens, but its success has shown community partners that Extension is a local food leader and a key player in advancing community agriculture projects. NC State Extension's Local Food Program Team partnered with two

organizations to build a **Network of Farmers Market Managers** to better respond to the unique needs of farmers markets in the state. These three organizations host regular webinars and other virtual gatherings for the emerging network. In addition to providing a space for markets and support organizations to network and collaborate, the network was able to coordinate with state government and law enforcement to keep markets open during the COVID-19 shutdown and provided data to the state government that resulted in $750,000 in relief funds for farmers markets. In March 2020, 49 individuals registered for the first webinar. As of the end of 2021, the group has expanded to 120 contacts on the email list. **Extension helped create stronger local food systems by building capacity for Farmers Markets.**

Briefly describe how the broader public benefited from your project's activities.

Cooperative Extension continues to play a key role in increasing local food system capacity by supporting and promoting farmland preservation. To bring a much broader range of county citizens together to learn about Lincoln County farmland, Extension personnel worked with farmers to coordinate a sponsored **farm-themed concert**, beginning with a sponsored mixer and dinner well attended by county farmers, farm families, and county commissioners. A "State of Our Agriculture Address" was featured, as well as introductions of each farm family to the commissioners. Later that evening, a crowd of over 2,000 people gathered for a concert featuring a popular band. The concert included 4 brief, high-energy presentations on farmland and farming, as well as an appreciation of farmers and a clear call to favor local agriculture and farmland supportive policies. The crowd response was energetic and very positive. This was the largest public gathering in Lincoln County history that allowed farmers to directly address and influence the public for the sake of farmland preservation. Farmers expressed appreciation and gave a very positive response to being able to visit with each other, discuss important issues as a group, and influence our local community representatives. The commissioners responded very positively as well. The public was enthusiastic and responsive to the presentations in the concert, cheering for farmers when asked to and reacting energetically to prompts for responses during the presentations. Many people (including farmers, leaders, and the public) expressed appreciation and a desire to have a similar event next year.

NC Choices' USDA-funded Beginning Farmer and Rancher Development program identified and partnered with solar-farm, silvopasture, and land trust contacts to develop **land-sharing opportunities** for beginning farmers. In 2021, Extension helped install infrastructure and/or developed lease arrangements, budgets, and applied one-on-one technical assistance for land trust, solar, and silvopasture farmer/landowner partners, including a significant expansion of solar grazing partnerships. Over 10 beginning farmers are now actively farming on leased land opportunities in NC. Extension helped secure two new beginning farmer land-pair partnerships.

Wilson County approved an ordinance to allow **Voluntary Agricultural Districts (VADs)** in 2004. VADs help to promote agriculture and preserve farmland, increase countywide recognition of and pride in the agricultural community, encourage the economic health of agriculture, and increase the protection of agriculture from non-farm development and nuisance lawsuits. Extension provides leadership to the Wilson County VAD and works with the Wilson County Agriculture Advisory Committee, appointed by the Wilson County Commissioners, that oversees the VAD. When first created, 39 farms representing 3,379 acres enrolled in the program and made a voluntary commitment for 10 years. Recent population growth in Wilson County has re-emphasized the importance of the program, so Extension distributed information on the VAD, contacted all farms currently in the program, received a commitment from them to re-enroll, and encouraged farms not in the program to enroll. Twenty-nine new farms representing 943 acres have since enrolled in the program. This brings the total to 68 properties representing 4,322 acres in the VAD program in Wilson County. In addition, two VAD applications were found not to be enrolled in the Wilson County Present Use Value taxation program. Extension made them aware of the PUV program and how the program can save the landowner in taxes.

Cleveland County updated its **Comprehensive Land Use Plan** in 2021, to create a guiding document used by local elected and appointed officials planning for developmental growth, economic growth, zoning, and more. The farming community was concerned that the draft plan targeted a large segment of the county for future secondary growth (low-density housing and retail), with no consideration of the potential impact on commercial agriculture, needed a voice in the planning process. NC State Extension partnered with the Cleveland Soil & Water Conservation District to convene meetings with leaders in the local farming community. The coalition sent a proposal to the County Commissioners, asking that "Prime Agricultural Land" be identified in the plan. Supporters also attended County Commission meetings to speak in support of the proposal and to stress the importance of agriculture to Cleveland County's economy and quality of life. County leadership adopted the proposal, issued a proclamation recognizing agriculture, and committed to keeping agriculture in focus when making future decisions on land use.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to

communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

The following professional development workshops were provided by Extension Specialists for Extension Agents in 2021 to facilitate the use and transfer of new research-based knowledge:

- Creating a game plan to develop entrepreneurial farmers
- Farm School Online Course
- Introduction to Small Farm Bootcamp
- Land Summit: Right to Farm, Bona Fide Farm, PUV, VADs, & Tenancy
- Local Foods Program - Agritourism: Western NC Success
- Resources for Engaging Volunteers in Local Food Programming

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

Resilient localized food systems ensure a continual supply of safe, accessible food for all community members while supporting the economic vitality of farmers of all scales. NC State Extension increased access to locally produced food through food assistance collection and distribution programs such as food collection at farmers markets and venison donation programs. With Extension's help, local agribusinesses and farmers markets continued to increase direct consumer spending at farms and markets narrowing the disconnect between consumers and the agriculture community. Extension also fueled the continuous growth of robust local food systems by providing training, education, and guidance to new and beginning farmers. NC State Extension created opportunities to build resilient local food systems that promote food that is grown, caught, and raised within North Carolina.

4-H Youth Development

Project Director
Lauren Hargrave
Organization
North Carolina Agricultural and Technical State University
Accession Number
7001849

4-H Leadership

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Youth ages 5 - 8 are in the beginning phases of developing the necessary skills for social development. Many communities lack resources and opportunities to provide developmental activities contributing to overall success, which may cause a gap in developmental growth. Additionally, decision-making is an important skill to teach youth to prepare them to become independent and responsible adults. Providing youth with an opportunity to brainstorm, share ideas, interact with their peers and family, and solve problems contributes to their future success as leaders in society. However, youth who are Black, Indigenous and People of Color (BIPOC) often lack access to an extensive network of community-based mentors with whom they share a cultural background and who serve in important relational roles related to post-high school pathways. It is imperative to introduce post-high school pathways to BIPOC communities, so they have the knowledge to making informed

decisions about their futures and the availability of resources to achieve their goals. Youth should be encouraged to broadly explore post-high school pathways and access critical information when working towards those goals. However, recruiting and engaging limited-resource teens in structured leadership programming initiatives is challenging. Organizations such as 4-H compete with a multitude of activities that capture the attention of our teen audiences. Providing leadership training is necessary for youth development and well-being. Middle and high school youth need to be equipped with the tactics needed to lead in their communities, at school, and in structured 4-H programs. Although it's important to encourage teens to participate in numerous experiences, it is imperative that they participate in leadership-driven opportunities. Since leadership opportunities are limited, particularly in underserved communities, it is necessary to provide this opportunity to equip them with the skills they need to thrive in a competitive society.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

The 4-H Clover Kit Program provides communities with hands-on activities and resources designed to nurture the development of life skills essential for the cognitive, social, emotional, and physical development of 5-8-year-old children.

Additionally, the Clover Kits provide youth with an increased understanding of 4-H, self-awareness, and cultural perspectives, and help them develop positive attitudes about learning and the world around them. These leader-guided activities lead to identified goals and objectives developed by each participant's ability to demonstrate the goals/standards shared, particularly in community, school, and home settings. This program enables youth to:

- Develop social, emotional, and physical development, and decision-making skills.
- Learn more about themselves and the world around them.
- Gain knowledge in 4-H content areas (STEM, leadership, healthy living, civic engagement) through experiential learning.
- Develop positive attitudes about learning.
- Develop life skills in self-understanding, social interaction and experiential learning.

During the 2021 pandemic year, three Cloverbud trainings were scheduled but postponed due to COVID-19 guidelines affecting face-to-face programming. While we could not facilitate face-to-face initiatives, other delivery modes (i.e., virtual training and micro-webinars) were made available.

The 4-H Mystery series introduces 4-H programming concepts (i.e., civic engagement, STEM, leadership & healthy living) to youth to enhance decision- making skills, teamwork, and family time. In 2021, the 4-H Mystery Series provided opportunities for K-8th grade youth to engage with others and solve problems. Offering the Mystery Challenge series not only provided youth with the opportunity to participate in problem-solving activities, but also provided youth with opportunities to work together as a team with other family members and peers. During June and July 2021, a new challenge related to healthy foods, STEM, and agriculture was shared three times each week via social media and email. To reach more participants, county Extension professionals then reshared the challenge with their 4-H members and other school-aged audiences. Participants had 24 hours to complete the challenge and share their results via social media. To date, this new initiative has been facilitated for one summer.

The Nia Pathways and Purpose program is developing in phases. Two counties were identified during 2021 (phase 1 of the program) to facilitate a pilot. The identified counties were Martin and Wilson. In addition to the NC counties, program facilitators worked with three districts in Wisconsin through partners at University of Wisconsin at Madison. The pilot phase included five counties in North Carolina and Wisconsin. To date, the NC A&T 4-H specialist has hosted monthly check-in

sessions with local and statewide partners and hosted one of two teen council meetings to plan and implement the Nia project. There were six teens in attendance for the first teen council meeting. The intent was to host small groups to engage in rich discussion.

For the Leaders in Training (LIT) program, 4-H members attended a one-day, three-hour 4-H LIT session where they learned about leadership skill development, brand building, and self-discovery. Then, the youth participated in a one-day residential experience where they participated in workshop sessions focusing on leadership 101, digital leadership, impress when dressed, mock interviews, team building, and identifying leadership style. On average, funding allows us to offer the residential program to 22 youth each year. Due the pandemic in 2021, we could not host a face-to-face experience, but we were able to host a virtual experience. As a result of the virtual delivery model, we extended the opportunity to 4-H youth across the state. We designed marketing materials and shared them with 4-H and CRD agents to market the program.

Training was also provided for the Toybox Leadership program. The training focused on the following concepts:

- Lego Bricks: Relationships—Building Begins with Connecting.
- Slinky Dog: Vision—Pull—Then Be Patient.
- Play-Doh: Mentoring—The Mold Makes the Man.
- Yo-Yo: Creativity—It Only Happens When You Let Go.
- Mr. Potato Head: Mentoring—The Right Face for the Right Place.
- Rubik's Cube: Ethics—Making the Right Turn.
- Rocking Horse E?iciency—All Show and No Go.
- Little Green Army Men: Strategy—Success Is in the Set-Up.
- Lite-Brite: Message—Illuminate to Communicate.
- Weebles: Endurance—Staying Down Is Not an Option.

To develop Youth Stepping Fourward, modifications were made to an existing program called Community Voices, which emphasizes the essential skills and strategies youth can use to become influential leaders and understand their role in civic affairs. The program was implemented in three phases: training Extension professionals, youth leaders, and 4-H volunteers to serve as facilitators; convening training sessions for youth participants; and youth executing their serving learning project. The program followed a participatory and facilitator style of training, and the program was formatted so that it could be conducted virtually. The training sessions were two hours long and ran over nine to 10 weeks. During the sessions, participants actively discussed and worked as part of a team to address a community issue of shared concern. The course

modules focus on the skills of successful leaders, including leadership styles, adopting a shared leadership approach, communication, consensus building, and action planning. In addition, 4-H agents and their 4-H groups spent an additional two to three months executing their respective community service projects from planning to implementation.

Briefly describe how your target audience benefited from your project's activities.

To date, 65 4-H Extension agents have been trained to facilitate the Cloverbud curriculum and implement the Clover Kits to youth ages 5-8.

In Graham and Yancey counties, 29 youth engaged in Cloverbud activities, focusing on healthy diets and exercise, bike safety, strangers, manners, birds, Christmas traditions and culture, and sewing. There was a total of seven sessions presented over 10 hours.

There were 20 4-H Mystery Challenges released in June and July 2021, engaging 300 families via social media. Offering the 4-H Mystery Challenge series allowed youth to participate in problem-solving activities and allowed families the opportunity to work together as a unit promoting family time. Participants submitted pictures and provided feedback on the enjoyment they experienced. During times of uncertainty caused by the ongoing pandemic, this opportunity provided families with activities to keep them engaged and operating with a sense of normalcy.

A Bertie County 4-Her, has done her best to maximize all opportunities that 4-H has offered her in her 12-plus years of participating in the Bertie County 4-H program. During her Cloverbud and Junior 4-H years, she participated in camping, programs, in-school enrichment, and special interest programs at the state, district, and county levels. As she matured into senior-level 4-H programming, her interests in greater leadership development grew. She began her leadership training by working on the county-level programming through Bertie County's Cooking & Health Eating Camps. Her growth on this level earned her the opportunity to attend National 4-H Conference. As her leadership skills grew, so did the reach of the programs she was involved in. The 4-Her and other teen leaders were trained as Healthy Habits and National Youth Science Day Youth Teachers. This group of teens conducted in-school and after-school programming and helped design and implement Bertie County's Summer Enrichment camps that reached over 150 youth in Bertie County. While very involved in 4-H, she found time to grow her SheBeKurly Hair Products brand, maintain a 3.56 GPA, participate as a dual-sport athlete, and complete the youth component of the Community Emergency Response Team. Her active experience in 4-H allowed her to gain the confidence to run and be elected as the 2020-2021 4-H Northeast District President. She is the first African American female and the first from Bertie County to hold this o?ice. As she continues to implement the leadership knowledge gained, she will continue contributing to her clubs, her community, her country, and her world through her participation in NC A&T's Leadership in Training (LiT) Program.

While we expected more youth to participate, in LiT, participation numbers were lower for a virtual audience. We had six counties represented and 25 participants. We also experienced competing 4-H virtual events (i.e., NC 4-H Citizenship Focus). To date this leadership program has enrolled 80 LiT participants, both virtual and face-to-face, since its inaugural year.

To date, 42 4-H, FCS and CRD Extension professionals have been trained to facilitate the Toybox leadership program with middle/high school youth in their counties. Additionally, 32 teens who are active in 4-H County Council, Teen Leads and Healthy Habits, have been trained. Because of the Toybox Leadership program, teen participants can lead 4-H community meetings, assist with project action planning and visioning, and communicate with community stakeholders and other officials.

Overall, a total of 65 youth participated in the Youth Stepping Fourward (YSF) program. Forty of the youth were from limited-resource families and 25 were considered non-traditional.

Nine youth in Chatham County identified two issues they wanted to work on for their YSF service-learning project: food insecurity and community beautification. In a combined effort, the youth were able to collect 331 pounds of food, benefiting the two food pantries in their county. The youth group also completed phase 1 of a beautification plan for the Union Taylor Community Center.

The N.C. A&T 4-H specialist partnered with the director of A Better Change, A Better Community (ABC2), who also serves as a 4-H leader, to sponsor YSF to their youth constituents. Twenty-seven youth participated in YSF in Halifax County. They met bi-monthly to conduct the leadership development workshops. Their service-learning project used GIS coding and mapping to help young people visualize their community and local food system, discuss the current state of the system, and realistically design solutions to address food insecurity and social determinants of health. In addition, ABC2 created maps for the Healthy Food Access Mapping (H-FAM) Project for their five-county region. Led by the Upper Coastal Plain Council of Government with funding from Kate B. Reynold Charitable Trust, the H-FAM project utilized the knowledge and expertise of key community stakeholders to assess the current local food system in the region. They identified the gaps and challenges in accessing healthy food, particularly within under-resourced communities. YSF youth participants were able to capture different data points such as demographics, local food consumption, restaurant spending, other regional assets (fresh food growers, distributors, processors), to name a few. Their work with the H-FAM project received 1st place in a state GIS competition. They also partnered with the local county Extension Center to complete walk audits, which effectively engaged diverse community representatives in defining physical or structural aspects of the community they want to improve.

Eight youth participated in the YSF program in Harnett County. This group constructed community blessing boxes in response to the youth wanting to give back to their community and help families and individuals in need. The 4-H participants built and stocked the boxes and strategically placed them around their county, particularly in high-need areas. Their program partners included: First Free Will Baptist Church, Cutts Chapel Church, Noni Stash, TTC Construction, Harnett County Food Pantry, Riverside Community Action Network, Harnett County Arts Council, and Recruiters for Christ Food Pantry.

Four youth participated in the YSF program in Hertford County. After facilitating leadership development workshops for youth, the county 4-H agent and their youth conducted a forum with their town's Mayor's Community Intervention Task Force. The task force included the town mayor, teachers, mental health workers, religious organizations, juvenile justice representatives, and other community youth groups. Utilizing the training they received through YSF, the teens captured input by reaching out to 40 youth through summer STEM and civic engagement programs to examine how youth are affected by community issues. A after the presentation, youth facilitators led a discussion on improving youth experiences in the community. In addition, the YSF youth utilized interactive tools, such as Menti and Dash robot videos, to engage their peers and collect their perspectives on issues they face daily. The youth presented the results to community leaders, and some of the top issues youth believed needed to be addressed included mental health, violence, and bullying. As a result of their leadership in this project, these 4-H teen facilitators recruited community leaders to serve on the planning committee for their upcoming Voices and Vision project, which will allow them to create space for community dialogue around youth issues. They were also able to take on new leadership roles when they accepted the mayor's invitation to serve on the youth advisory council. Furthermore, a local community organization asked the teen facilitators to serve on their committee regularly to ensure youth voices are represented.

Seven youth in Mitchell County identified food insecurity as a community issue and, subsequently, as part of their community service project, the youth planted and tended a garden throughout the summer, raising squash, cucumbers, tomatoes, eggplant, and herbs. All 110 pounds of vegetables harvested were donated to a local food pantry. The 4-H group partnered with the Mitchell County Public Schools, Social Services, and Bakersville Baptist Church to complete this project.

Briefly describe how the broader public benefited from your project's activities.

The broader public benefited from the program as it prepared youth to become leaders. Leadership skills contribute to society overall, helping to grow people that contribute to their communities and think critically. Also, the community service projects provided community members with food and other necessities. That means the number of individuals facing hunger decreases, and it can eventually lead to reduced government funding needs. As communities take care of one another, it reduces food insecurity and increases accountability.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

The Clover Kits are experiencing an expansion with the creation of Clover boxes with specific themes. Six themes have been identified, with each theme containing materials for 75 boxes. The Clover boxes are designed to enhance creativity at home while working alongside family members. The Clover boxes will be mailed to families with all materials needed to complete

the activities.

The Mystery Series will be facilitated again during Summer 2022. Currently, new lessons are being designed for dissemination. We have re-designed the frequency of dissemination. Challenges will be released bi-weekly instead of weekly via social media. Additionally, we plan to coordinate with other university department experts to enhance the quality of the challenges to continue focusing on community development, STEM, agriculture, and other essential topics.

Nia Pathways with Purpose meetings:

1. UW-Madison & N.C A&T Joint Meeting

2nd & 4th Mondays (May -December 2021)

16 meetings

Time: 4-5 pm

2. NC A&T Program Collaborators Meeting

2nd & 4th Tuesdays (May-December 2021)

16 meetings

Time: 4-5 pm

3. NC Community Partners Meeting

3rd Thursdays (July-December 2021)

16 meetings

Time: 10-11 am

Beginning in April 2022, the Pathways with Purpose curriculum will be piloted at two sites: a middle school in Martin County and a Community center in Wilson County. We are targeting 15-20 youth to be a part of the first cohort. The youngest participants in grade six will participate through grade nine, while the oldest participants may participate from grades eight through 11. This program is the result of a five-year grant program. While phases 1 and 2 encompass the 2021-2022 program year, the program phases will continue to expand in years two though five.

Currently, we are in the process of developing deliverables for the Toybox Leadership program. We are designing worksheets and handouts that align with each leadership tactic to engage our participants better.

Plans are underway to offer the Leaders in Training program on campus this year. Youth will be recruited to attend the residential program. While the virtual programming delivery mode was not as successful due to Zoom fatigue and conflicting scheduled events, we are hopeful the 2022 program will overcome those issues to once again become a successful leadership event.

66 youth and adults were trained to become YSF facilitators.

We recruited four additional counties during the fall of 2021 to expand the YSF program – Vance, Warren, Catawba, and Haywood. We conducted a train-the-trainer training in October. With the remaining funds, we want to support these counties as they lead the YSF training series with their 4-H participants in the first quarter of 2022 and execute a service-learning or community project by the second quarter of 2022.

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Hard skills are essential, but they can be unproductive without soft skills. Soft skills are necessary for youth to succeed in education, job training, independent living, community participation, and the workplace. Soft skills are usually obtained through life experience or unique learning environments and approaches. Several studies have shown that many youths are not being prepared with the soft skills needed to succeed in the workplace.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

The “You’re Hired” program provides a unique blend of teacher-led activities, virtual training, and small group activities to support the development of soft skills in middle school-aged youth. The modules focus on personal branding, communication, conflict resolution, customer interaction, responsibility, and time management. The NC A&T 4-H specialist provided professional development for 36 NC 4-H staff, where they received the curriculum guide and a set of youth guides to implement the program in their counties. NC A&T staff implemented the program with 57 youth.

Briefly describe how your target audience benefited from your project's activities.

Over the last four years, the Bertie County 4-H program focused on preparing limited-resource teens for careers and the workforce through a unique teen leadership program. This teen leadership program encouraged and challenged participants ages 13-18 to identify their strengths and interests while conducting programs utilizing the Teens as Teachers model. Additionally, the Bertie County 4-H agent intentionally built soft skill development and career exploration into the 72 two-hour meetings designed for the 15 teen participants. Through the 2,160 hours invested in this program, 12 teens have earned a job and were recognized for their professional conduct in challenging situations. Three teens have explored entrepreneurial opportunities that yielded more than $1,000 in income. Six teens have pursued higher education and are confident in their choices for education. They shared that their confidence arises because the Bertie 4-H program helped them identify their true interests, strengths, and dislikes. Three teens have purchased vehicles, paid for their insurance, and maintained 4-H participation and good grades in school. Two were promoted in their jobs more than twice in one year. Due to being promoted three times in under two years, one participant significantly contributed to his family purchasing and paying off a house. Seven participants were selected to participate in national-level programming due to their leadership ability and experience. Six participants have conducted more than two six-hour programs without assistance from the 4-H agent during program delivery.

To prepare youth for the workforce, the Bertie 4-H agent created a Teen Leaders program to strengthen teens' soft skills and help them identify and utilize their strengths. Using the Teens as Teachers model, teen leaders are placed in charge of designing, conducting, and evaluating a minimum of one six-hour program under the guidance of the 4-H agent. In addition to leadership and teacher training, the teens participated in financial literacy workshops designed to help them make wise financial decisions.

A first-generation 4-Her and American became active in the Bertie 4-H program in the 8th grade. Over four years, this young man participated in local, state, and national 4-H programs where he learned and applied the soft skills he learned. After graduating high school, he earned a job at Bertie County's largest employer, Perdue. The young man frequently communicates with the Bertie County 4-H agent, and he shared how he was promoted three times in under 18 months. He shared with the 4-H agent that he was promoted because of his leadership training in 4-H. He mentioned his supervisors recognized his ability to communicate with his coworkers. The promotions in leadership he earned also came with a significant financial reward. This increase in pay allowed him to purchase a vehicle and pay for his car insurance. The young man continues to rise to the top in his line of work. When he can, he also willingly volunteers with Bertie 4-H programs.

Additionally, as a result of the Teen Leaders program, another Bertie County youth accumulated 430 hours in the program. She learned how to handle difficult conversations, work with peers who think differently than her, and lead a group of peers to execute a quality program for K-6th grade youth. This young lady used her soft skills to apply for and gain employment as a camp counselor at the Eastern 4-H Center for the 2021 camping season.

4-H agents reported how well this teen worked with the youth, camp counselors, and 4-H agents throughout the summer. The Eastern 4-H Center Director shared directly with the Bertie County 4-H agent the areas where the Bertie 4-Her was strong, and they aligned directly with the soft skills that the Bertie County 4-H agent taught her. She applied what she learned in the

Bertie County 4-H program and was recognized as a counselor that the director "did not have to worry about." Additionally, the center director stated that if the young lady wants to return next season, she has a job waiting for her.

Briefly describe how the broader public benefited from your project's activities.

N/A

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

In response to COVID-19, during 2021, the program has been in development to be implemented as a virtual program. The process to transform the in person program to virtual is still underway.

Critical Issue

Improving Plant and Animal Agricultural Systems

Influence of Environmental and Cultural Factors on Weed Management in Agronomic Cropping Systems

Project Director
WESLEY EVERMAN
Organization
North Carolina State University
Accession Number
1024761

Improved Integrated Weed Management Approaches

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Selection of herbicide resistance in weedy species has been increasing at an alarming rate for the past 20 year, and subsequently we have been identifying more species with resistance to multiple modes of action. The management of these species will require integrated weed management approaches that capitalize on the strengths of our crop species and the weaknesses of the weedy species.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Research on integrated weed management systems to manage herbicide resistant weeds in North Carolina has provided growers in our state with valuable tools and knowledge which has reduced the impact of pesticide applications on non-target areas, reduced the cost of weed management on a year to year basis, and lead to the introduction and adoption of new management techniques. Growers have adopted more widespread use of cover crops, early burndown applications, and residual herbicides to keep fields clean leading into the production season. The use of integrated management practices has taken the selection pressure off POST herbicides used in cotton and soybean, leading to prolonged utility of current POST herbicide options while they are beginning to fail in other areas of the country.

Additionally, research on critical period of weed control, weed - crop competition in the presence of soil moisture stress, and other studies where weed biology and competition were key factors, has lead to improved understanding of crop-weed dynamics in different environments which in turn have lead to more effective recommendations for growers.

Briefly describe how your target audience benefited from your project's activities.

Growers and crop advisors have an enhanced knowledge about herbicide resistance in the state, and are better prepared for avoiding and managing resistance in their own operations due to our research and outreach activities. Additionally, they have a greater understanding of the dynamics between crops and weeds on the landscape and how to better manage their crop to

reduce competition with weeds and improve yields.

Briefly describe how the broader public benefited from your project's activities.

The broader public continues to benefit from our growers safely and efficiently producing low cost food for them, with minimized environmental and financial impacts.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Since I have a 60% Extension appointment, all my research has importance to the agricultural community. I have provided dozens of presentations at county, state, and regional meetings to thousands of growers, practitioners, and researchers which increases the knowledge around herbicide resistance, integrated weed management practices, and crop-weed competition.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

The number of weed species with resistance to multiple herbicides is increasing at an alarming rate. NC State research on integrated weed management systems has provided growers with valuable tools and knowledge, reducing the impact of pesticide applications on non-target areas, reducing weed management costs, and leading to the introduction and adoption of improved management techniques, such as more widespread use of cover crops, early burndown applications, and residual herbicides to keep fields clean leading into the production season. In addition, NC State research on weed control has led to improved understanding of crop-weed dynamics in diverse environments, in turn leading to more effective recommendations for growers. Through NC State's integrated research and Extension weed management program, dozens of presentations have been delivered to thousands of growers, practitioners, and researchers to advance understanding of integrated weed management and improve yields. This project's results exemplify the progress being made through the North Carolina Plant Sciences Initiative, a major interdisciplinary effort designed to address the biggest challenges facing agriculture today.

Agronomic Crop Production Systems

Project Director
Meredith Weinstein
Organization
North Carolina State University
Accession Number
7000165

Research-Based Information and New Technology to Empower Agronomic Crop Growers to Make Better-Informed Decisions

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

North Carolina agronomic crop producers grow approximately 3.6 million acres of row crops annually, with the highest acreage being planted with soybean, corn, cotton, and wheat ranked in order respectively. Row crops contributed nearly $2 billion in sales to North Carolina farms, as reported in the 2020 USDA State Agriculture Overview. Most counties in the state grow corn, soybean, and small grains (wheat, barley, or oats), with cotton being confined to fewer, better-suited areas of the state.

North Carolina crop producers face increasingly complex environmental, financial, and logistical challenges in growing row crops. Profit margins for corn producers have remained extremely tight in recent years. Rising fertilizer costs and other variable expenses are impacting grain producers, with a projected $200 per acre increase or greater in 2022, and growers continuously struggle to optimize peanut production due to challenges in timing maturity at harvest. In addition, cotton producers face large upfront production expenses in the form of cotton seed costs, and the rapid turnover of modern cotton varieties in the market makes it difficult for producers to develop best practices for variety selection.

According to the United Nations-FAO, the world's population will grow from 7.9 billion today to nearly 9.7 billion by 2050. To meet demand, agriculture in 2050 will need to produce almost 50 percent more food, feed and biofuel than it did in 2012. Research is needed to develop new and hybrid varieties and best management practices to increase crop production efficiency through increased yields, improved quality, and decreased input costs. To feed this growing population, NC State Extension needs to effectively transfer knowledge of innovative technologies, new varieties, and research-based agronomic crop production best management practices developed or recommended by NC State researchers to crop producers and industry representatives; effectively transfer knowledge and skills into practical applications for crop producers to adopt; and empower growers to make better-informed decisions.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

To support sustainable growth in row crop production, NC State Extension Specialists developed innovative products, technology, and research-based agronomic crop best management practices (BMPs) through a combination of methods, including applied research, official variety testing, and on-farm variety evaluation. Extension Specialists and Agents transferred knowledge of these innovations and practices to producers through meetings, research and demonstration plots, field days, expos, workshops, on-farm consultations, and educational media. As a result of NC State Extension programs, **45,911 best management practices related to nutrient management, conservation, production, pest management, business management, and marketing were adopted by agronomic and horticulture crop producers.**

- NC State Extension Specialists disseminated new agronomic crop information and best practices through the publication of 91 **peer-reviewed Extension publications** to educate Extension Agents, producers, and members of industry.

- NC State Extension Agents used **social media and mass media** to provide educational information to crop producers. Agents had a social media reach of 1,299,179 and a mass media reach of 25,574,049. Extension Specialists posted educational content on social media 1,129 times with a reach of 256,271 and created 57 newsletters with a reach of 1,096.

- NC State Extension Specialists maintained 13 agronomic crops, pest, and disease **web portals** containing 10,909 individual web pages. 35 new web pages were added in 2021 along with 359 new educational posts made to existing pages. The crop, pest, and disease websites maintained by Extension Specialists were viewed 677,886 times.

- NC State Extension Specialists produced 60 on-demand **educational videos** delivering information on agronomic crop production viewed 30,307 times.

- Extension Agents delivered **in-person and virtual training** to 7,292 growers on agronomic crops and another 9,897 individuals attended pesticide safety training programs. An additional 9,554 growers attended training provided by Extension Specialists.

The Pasquotank Cooperative Extension Center's agriculture program, with the assistance of Extension Specialists, provided relevant and timely information to growers and others in the agricultural community by producing 15 **educational videos** covering wheat and soybean production, corn and soybean pest management, and corn fertility, which attracted 1,120 views and allowing access 24/7 to information that people may not have otherwise had the opportunity to obtain and utilize. In Jones County, Extension produced 18 educational Crop Sense **podcast episodes** featuring interviews with Specialists. Crop Sense episodes are short, stackable 15-to-20-minute segments that answer specific questions on distinct topics so that growers can choose relevant episodes. The episodes, that provide key information about crop production, profitability, and environmental sustainability, have been downloaded 2,165 times. **Empowering NC growers by providing on-demand resources to increase the knowledge of best management row crop production strategies is just part of how we are growing the future of agriculture in North Carolina.**

Winter wheat is an economically important grain crop in North Carolina, producing almost $140 million in revenue for NC farmers. But Italian ryegrass is an herbicide-resistant weed that plagues winter wheat yields, especially in NC's Piedmont region. In many fields, once the weed appears, it can't be chemically controlled. NC State Extension Specialists have successfully drone-identified early-stage Italian ryegrass in winter wheat, using **remote sensory technologies**, allowing for holistic weed management options. Early Italian ryegrass identification opens the door to early-season management techniques beyond herbicides. Knowing where weed populations exist would empower growers to make informed decisions. This work creates future opportunities for Extension Agents to assist growers with image collection, processing, and interpretation. Agents can then collaborate with Extension Specialists to analyze the field data for various biotic and abiotic stresses then farmers or agronomists would translate field results into prescription herbicide application files or drone sprayers for precise application. **Enhancing NC agriculture by transferring and utilizing practical, in-field decision-making tools, including remote sensory technologies, is part of how we are growing the future.**

Briefly describe how your target audience benefited from your project's activities.

In 2021, Camden County Cooperative Extension offered a broad range of research-based agricultural programs and materials, including on-farm consultations, collaborative regional field days, production meetings, variety trial demonstrations, and a newsletter series. These programs supported the adoption of BMPs for nutrient and pest management, variety selection, business management, and marketing, securing an estimated $1,712,349 in additional revenue for local producers. The **Southern Piedmont Corn and Soybean Field Day** was held in Cleveland County. Extension provided growers with information on BMPs related to grain bin safety, soybean and corn production, and grain marketing. This field day was attended by 115 individuals. Attendee feedback indicated that the field day improved knowledge of yield optimization, disease, and pest management and that growers were interested in using new practices to improve yield on their farms. The **Northeast Ag Expo Winter Meetings** used online technologies to bring subject matter experts to local farmers. The Expo offered 7 meetings, each averaging 46 attendees, with 322 total participants. Post-meeting evaluations indicated that 49 of the 51 soybean growers and 37 of the 38 corn growers expected increased yields because of attending the Winter Meetings. The **Northeast Ag Expo Summer Field Day** provided growers and other members of the agricultural community with information on cotton and peanut production, technology, and crop-related practices. The 47 attendees represented 4,400 acres of cotton and peanuts. As part of the event evaluation, attendees valued the increase in bushels/acre gained over the past 12 months from information provided by Extension at last year's field day at $568,158. **As a leader in experiential education, NC State Extension equipped row crop farmers to effectively transfer best management practices into practical applications.**

Variety selection is one of the most important decisions growers make every year. It can be challenging due to the abundance of varieties offered that are suitable for a wide geographic area. Growers look to Extension's variety demonstrations as their key source of local, unbiased information on variety selection. Cooperative Extension in Camden, Chowan, Currituck, Gates, Pasquotank, and Perquimans counties coordinated 6 **variety demonstrations** and presented yield data to farmers, allowing them to see which varieties performed best on nearby farms. Decisions about 60,150 acres were informed by this data, resulting in an estimated $2,232,768 in additional revenue for corn producers through improved variety selection. Local variety information is a critical educational tool in production agriculture in Johnston County because of the county's wide range of soil types and rolling to reasonably flat topography. **Variety trials** included cotton, corn, soybean, and wheat. By utilizing the local variety yield results and selecting varieties with higher yields, county wheat yields can be increased by 22 bushels/acre, corn yields can be increased by 39 bushels/acre, cotton yields by 258 pounds/acre, and soybean yields by 13 bushels/acre, equating to $6,000,000 in added value annually. **NC State Extension provided solution-driven research and technology to empower growers to make better-informed variety selection decisions.**

Cotton seed is one of the costliest inputs of the total production costs of cotton. Cotton farmers are also faced with modern cotton varieties entering the market very quickly, with very little supporting data from the pre-commercial stages. This makes the selection of cotton seed an important yet difficult decision. The **NC On-Farm Cotton Variety Evaluation Program** consists of 16 to 17 trials in producers' fields across the state annually. The varieties entered are determined to be the most widely adapted and best-fit varieties of each commercial brand for NC producers, and collectively this program captures the predominant soil types in all regions, geographies, and environments in NC's cotton belt. Trials are established in all parts of the state, based on each region's contribution to total cotton acreage. After one year of testing, growers are trained on how to manage each variety and in what scenarios or type of environment each variety should be positioned for maximum yield potential. The 2020 on-farm program resulted in an estimated economic impact of $9,999,150 to $13,083,000 in 2021, and the potential economic impact of the 2021 program is estimated to be $53,550,000 to $115,850,000 in 2022 and beyond. **NC State Extension demonstrated the utility and applicability of variety-selection decision models utilizing meta-data gathered from the NC State Official Variety Trials to enhance the utilization of Extension-developed decision-making tools by crop producers.**

Field studies conducted by Extension Specialists found that corn plants that emerge first had more rows of kernels on the cob and more kernels per row, resulting in more grain weight and yield compared with seedlings that emerge later. Twenty-three **field trials** were conducted over 6 years using innovative techniques that marked corn seedlings as they emerged to

determine the impact of time of emergence on ear characteristics and corn yield. Results from these studies were presented at meetings and conferences and at 3 agent training sessions. Growers in North Carolina responded to this information by developing new approaches for determining when to plant corn, by planting deeper, and by choosing hybrids tested in these studies that showed better emergence and early vigor. A technique was developed and presented to growers so that they can choose corn hybrids with good early emergence and growth characteristics. **NC State Extension conducted applied research to provide trusted solutions and empower corn producers to make better-informed decisions.**

Determining peanut maturity is an important production decision for peanut farmers. Maturity affects flavor, grade, milling quality, and shelf life. Cooperative Extension provided **peanut maturity clinics** to help producers determine the optimal time to harvest their crop. Using a pressure washer, the agent "blasts" the outer layer off the peanut pods. The color of the pod after blasting can indicate how mature the pod is. In Bertie County, 25 growers brought samples from approximately 3,572 acres corresponding to a potential minimum increase of $264,325 in grower profits. In Halifax County an event reached 15 farmers, who left the event with knowledge of the maturity levels of their peanut fields and were able to decide which fields would be best to dig first and which fields would be better left undisturbed for a few more days. Duplin and Sampson County produce around 17,000 tons of peanuts; Extension Agents held 6 Peanut Pod Blasting Clinics providing an economic value of over $7,514,000. The Northampton County Cooperative Extension Center helped 68 peanut farmers representing 3,226 acres determine maturity, which translated into an additional $387,120. Six pod blasting clinics were held in Chowan County, once a week, every week starting in September. In Pitt County, 32 growers reported an average increase in the yield of 427 pounds per acre, representing a potential value of $290,7683 because of the clinic. Wilson County Cooperative Extension pod blasted 16 samples that represented 1,040 acres of peanuts. Producers were able to increase gross income by $40,950. **NC State Extension provided tools and resources to help peanut growers make better-informed decisions and improve crop production efficiency through increased yields and improved quality.**

Briefly describe how the broader public benefited from your project's activities.

Agriculture and agribusiness combined is the leading industry in NC, where more than 45,000 farms occupy 8.3 million acres of farmland, accounting for 17.5% of all jobs in the state and an annual economic impact of $95.9 billion. NC faces population growth, loss of farmland, and impacts from climate change, which have affected agricultural and food systems. **NC State Extension leads efforts to solve global challenges and create economic, societal, and intellectual prosperity by merging creative, innovative ideas with purposeful action.**

Soil testing is the predominant way growers assess specific soil nutrient status and evaluate supplemental needs. Soil testing provides the backbone for nutrient management programs in modern, intensive agricultural production systems. Most science-based soil fertility recommendation systems derive phosphorus (P) and potassium (K) fertilizer guidance from soil test results. While soil testing has the common goal of determining where fertilizer is needed and how much to apply, soil testing laboratories in the USA differ in soil analytical methods, interpretative terminology, and philosophical approaches to fertilizer recommendations. These differences often result in different fertilizer recommendations among labs within and across states, leading to end-user confusion and reduced confidence in soil testing, which ultimately proves detrimental to application and educational efforts that encourage 4R Nutrient Stewardship.

NC State Extension Specialists are leading a national effort to address the interstate nutrient divide by creating the Fertilizer Recommendation Support Tool, or “FRST.” The project aims to develop a soil-test and crop-response-to-fertilization searchable web-based tool that provides more consistent, transparent, and science-based decision support for nutrient recommendations across the USA. FRST’s searchable database is designed to benefit both researchers and growers. Initially, it will support phosphorus and potassium recommendations for 15 major crops, including corn, cotton, grain sorghum, peanuts, soybean, and wheat. The tool is founded on a relational soil-test correlation and calibration database.

The FRST effort currently consists of 90 individuals from across the USA, and the participants are growing; all have volunteered to be part of this project. Agencies involved in the project consist of 38 land-grant universities in 37 states and 1 territory, 1 private university, 2 state universities, 10 ARS scientists, 3 Natural Resources Conservation Service personnel, 1 FSA, 3 private not-for-profit individuals, and 1 State Department of Agriculture employee engaged in this project. The database will reside at the National Agricultural Library so that it is accessible by all and provides perpetuity of this resource. New data from current trials are constantly being added. The group has plans to expand to other crops, cropping systems, micronutrients, and even worldwide growing regions in the future.

While many agricultural practices contribute to resource conservation, nutrient management addresses potential excess at the source. Limiting fertilizer application initially is vastly more efficient and environmentally effective than down-the-line mitigation strategies. **Because agriculture is tasked with feeding a growing world population on fewer acres of arable land, growers strive for production efficiencies. Sound nutrient management seeks to balance environmental stewardship and crop production goals. In the end, farmers and taxpayers stand to save millions of dollars annually.**

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

The following professional development workshops were provided by Extension Specialists for Extension Agents in 2021 to facilitate the use and transfer of new research-based knowledge:

- Abiotic Disorders
- Bees, Pesticides & Politics
- Burndown: Fall, Spring, and Everything In-between, Cotton and Peanut Agent Training
- Corn agent training
- Corn Insect Pest Management: Focus on Corn Earworm
- Cotton & Peanut Agent Training Field Day
- Cotton & Peanut Agent Training: Entomology
- Cotton Crash Course
- Cotton Management
- Cotton Physiology and Management Decisions
- Cotton Seed Quality
- Disease and Insect Update
- Entomology and Plant Pathology County Agent Training
- Field Crops Market Outlook and Agricultural Policy Updates
- Grains Agent Training
- Herbicide-resistant Italian Ryegrass and GPA and Nozzle effect on Cotton Injury

- Insights into Basis and Movement of Corn in NC
- Late-Season Peanut Disease Management Session
- New Variety Placement Tool for Wheat, Corn, and Soybeans
- Soil & Plant Tissue Sampling for Better Nutrient Management
- Soybean Agent Training: Future of US Soy
- Soybean Agent Training: Soybean Seed Quality
- Soybean Diagnostic Key Training
- Soybean On-Farm Research
- Stink Bug Management in Soybean
- Train-the-Trainer Toolkit for Grain Safety
- Twin v. Single-Row Grain Production: Which is best?
- Using Historical Basis to Inform Grain Marketing Decisions
- Variety Placement using the VST
- What is the future of hemp? Regulations, research, and markets
- Winter Cotton & Peanut Agent Training

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

According to the United Nations-FAO, the world's population will grow from 7.9 billion today to nearly 9.7 billion by 2050. To meet demand, agriculture in 2050 will need to produce almost 50 percent more food, feed and biofuel than it did in 2012. New and hybrid varieties and best management practices are needed to increase crop production efficiency through increased yields, improved quality, and decreased input costs. To support sustainable growth in row crop production, NC State Extension developed innovative products, technology, and research-based agronomic crop best management practices. These innovations and practices were transferred by Extension Specialists and Agents to growers through meetings, research and demonstration plots, field days, expos, workshops, on-farm consultations, and educational media. As a result of the knowledge gained from variety trials, peanut maturity clinics, demonstrations and other Extension programs, row crop

growers were able to increase yields and decrease production costs across commodities. NC State Extension is enhancing agriculture in North Carolina that supports thriving communities and provides all North Carolinians access to safe, nutritious food.

Animal Production Systems

Project Director
Meredith Weinstein
Organization
North Carolina State University
Accession Number
7000166

Solution-Driven Research, Technology and Technical Assistance to Increase Profitability and Reduce Environmental Impact of the Food Animal Industry

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

In 2020, North Carolina generated around $10.1 billion in agricultural cash receipts with the highest valued commodities being broilers, hogs, and turkeys. The food animal industry represents approximately 70% of North Carolina's agricultural economy. North Carolina is ranked #1 for production of all poultry species and #2 for overall hog and trout production nationally, with all 100 counties producing some type of animal-sourced product. NC has nearly 8 million hogs, 785,000 cattle and 916 million broilers (chickens grown for meat). According to an economic impact report, North Carolina's hog and pork processing industry contributes more than $7.1 billion in economic output to the state's economy and supports nearly 19,000 jobs. In addition, small ruminants remain a key source of meat for NC consumers. In fact, over the last 10 years, there has been an increased interest in small ruminant production in NC, especially meat goat production. The total populations of sheep and goats in NC increased by 7.4% and 4.3%, respectively, from 2018 to 2019. This has fueled an increased need for the education and training of small ruminant producers.

Although NC may currently be a leader in supplying meat products, the world's population is projected to surpass 9.7 billion by 2050. According to the United Nations-FAO, global meat production will have to increase to 455 million tons (from approximately 350 million tons today) to meet consumption demands. As a nation, farms and rangelands are being lost due to population growth and development and our farms have contributed to environmental damage due to greenhouse gas emissions, fossil fuels, and other pollutants. Farms will need to implement climate-smart agricultural practices and find innovative ways to increase food animal production on less land. To help feed a growing population, NC State Extension needs to effectively transfer innovative technologies and research-based animal science best management practices developed by NC State researchers to food animal producers and industry representatives, effectively transfer new knowledge and skills into practical applications for food animal producers to adopt; and empower producers to make better-informed decisions.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

To support increased profitability of animal agriculture, equine, and forage producers, Extension Specialists developed innovative products, technology, and research-based animal science best management practices (BMPs). Extension Specialists and Agents delivered information on BMPs to producers using workshops, certification programs, webinars, factsheets, newsletters, and specialized training sessions. Extension also led the development of new disease and waste management plans as well as novel technologies to enhance animal health. **As a result of NC State Extension educational programs and technical assistance, 4,457 producers increased their knowledge of nutrition, ration balancing, mineral supplements, breeding, and reproduction, and 4,310 producers increased knowledge of strategies for promoting animal health and welfare and reducing the risk of infectious diseases through proper use of vaccines, biosecurity, detection and identification of common diseases, appropriate use of animal medications, and mitigation of antimicrobial resistance transmission.**

- NC State Extension Specialists disseminated new animal science information and best practices through the publication of 71 **Extension publications** to educate Extension Agents, producers, and members of the industry.

- NC State Extension Specialists maintained 10 livestock, aquaculture, and poultry-related **web portals** containing 1,893 individual web pages. 16 new web pages were added in 2021 along with 161 new educational posts made to existing pages. The animal agriculture production websites maintained by Extension Specialists were viewed 119,783 times disseminating up-to-date research-based information and best practices.

- NC State Extension Agents had a **digital media** reach of 732,047 and a **mass media** reach of 16,997,264 providing animal and poultry science educational information.

- NC State Extension Specialists produced 74 **on-demand educational videos** on animal and poultry science-related topics that were viewed 38,437 times.

- 11,889 individuals attended **training** provided by Extension livestock agents, and an additional 14,540 individuals attended training provided by Extension Specialists.

- 1,582 **on-farm consultations** were provided by Extension livestock agents.

The animal feed industry represents about 70% of animal production costs, and the professionals responsible for animal feed quality, safety, and regulatory compliance require considerable training and access to emerging technologies, knowledge, and methods. This is a problem for those in rural and remote locations, where animal production operations are often located. To resolve this issue, 2 virtual short courses were developed to train new and experienced feed industry professionals about aspects of feed ingredient quality, feed formulation optimization and simulation modeling, and feed manufacturing and quality assurance. One virtual short course was designed for users of US soybean products (the major protein source used globally in animal feed). The first cohort of this 8-week short course enrolled 65 participants. The other course was designed for users of premixes (amino acids, vitamins, minerals, pharmaceuticals, enzymes, etc.) and enrolled about 360 participants from North, Central, and South America. Participant evaluations ranked the quality of the content, lecturers, and delivery of each of these virtual short courses very high, and nearly all the participants reported that they would adopt several of the concepts they learned in the course. **Increasing the knowledge of feed industry professionals and promoting the adoption of research-based BMPs by developing virtual training opportunities is just part of how we are growing the capacity of the food animal industry.**

In recent decades there has been a growing number of consumers who prefer products from production systems perceived as more respectful of the environment and animal welfare and a shift in the purchasing habits of consumers. Pasture pork production systems represent an alternative for these consumers. As with other livestock species, grazing pigs can pose environmental impact risks. Best management practices for pasture pork production systems were tested and are being disseminated by different means to alleviate the gap in information related to these differentiated production systems and technical support was offered to farmers. **Supporting farmers of the pasture-based pork supply chain in their search for more sustainable ways to produce pork is part of how we are growing North Carolina.**

Poultry Agents delivered a series of 6 **webinars** for small flock poultry producers, providing 420 people from 70 NC counties, 9 states, and 1 individual from Latvia with BMPs spanning general animal husbandry, poultry health, and disease management, and poultry processing. The webinars received glowing feedback from participants, with 90% reporting plans to implement new feeding practices and 87% reporting an enhanced understanding of brooding practices. Extension poultry Agents also published a **quarterly newsletter**, providing about 2,200 producers across 18 vertically integrated NC poultry complexes with information about a broad range of poultry production topics, including programs and incentives available to contract producers. **As a leader in experiential education, NC State Extension provided training and resources for poultry producers.**

Briefly describe how your target audience benefited from your project's activities.

Extension Poultry Agents and Specialists partnered with two poultry integrators and a manufacturer of production equipment to provide free training on 4 broiler farms to 63 production staff, indirectly reaching 600 contract growers. This training on the proper operation and maintenance of ventilation, heating, and cooling systems positively impacted the environment of over 300 million broilers across 3,000 commercial houses in Central and Eastern NC. The broilers increased their average daily weight gain and feed conversion, thus increasing grower profits and the quality of consumer products. In another effort, Extension Poultry Agents helped 12 poultry producers across 4 companies in 4 counties develop waste management plans, impacting over 1.1 million birds and ensuring proper processing and application of 14,000 tons of poultry waste on nearly 1,100 acres of NC farmland.

In Perquimans County, Cooperative Extension worked with public and private partners to provide over 45 credit hours of waste management training to licensed animal waste operators at the 2021 Northeast Pork Conference, generating an estimated $60,000 in added value for pork producers. Extension in Person County took advantage of a train-the-trainer session facilitated by the National Pork Board and subsequently offered pork quality assurance training and certification to 8 producers and transport quality assurance training and certification to 6 producers, generating an estimated $120,000 in added value.

Identifying avenues for utilizing lagoon sludge was a priority for swine producers across NC. Through applied research activities, a series of studies were conducted by Extension Specialists to characterize sludge and assess how different technologies can improve its properties. Outreach/field days were held to share preliminary findings and media content with Extension Agents, Technicians, and Specialists. Four hundred stakeholders and agents were introduced to principles of sludge processing (via composting, drying, pelletizing, and combustion) through training and field days. As a result, two full-scale greenhouse drying systems were constructed by a stakeholder to process sludge at a commercial scale. Several greenhouse structures were commissioned to dry sludge using solar greenhouses, and two pilot-scale sludge pelleting were commissioned at fertilizer plants to generate material for wider distribution. Following Extension training and outreach efforts across the state, 2,453 producers increased their knowledge of animal waste management practices, 5,191 animal waste management credits were earned, 1,400 producers implemented Extension-recommended BMPs for animal waste management, 198 on-site sludge surveys or equipment calibrations were conducted, and 206 waste utilization/waste management plans were developed or updated. **As a leader in experiential education, NC State Extension provided information, training, and waste management plans for poultry and hog producers to increase profitability and improve environmental quality.**

To support new sheep and goat producers, Cooperative Extension in Davidson County delivered 6 webinars in the fall of 2020 and the spring of 2021, covering topics such as fencing and facilities, nutrition, lambing and kidding, and reproductive management. The live webinars reached 582 individuals from NC and other US states and territories, and an additional 49 individuals requested the webinar recordings. Over 95% of the 290 surveyed participants reported increased knowledge of sheep and goat husbandry, and 64% reported implementing new practices thanks to the webinar, with the most common practices involving fencing and rotational grazing. As a result of Extension training and outreach efforts across the state, 2,383 livestock producers adopted Extension-recommended best management practices and production changes related to nutrition, ration balancing, mineral supplement, breeding, and reproduction. **Extension provided the latest research findings on best management practices to empower small ruminant producers to make better-informed decisions about nutritional requirements and reproductive practices.**

Cattle producers benefited from Rutherford County Cooperative Extension's collaboration with local and national partners to provide breeding soundness workshops which secured an estimated $227,500 in added profit. The producers were also provided tools to participate in value-added marketing channels for calf sales, including the use of electronic identification (EID) tags, co-mingled truckload lots, and quality assurance evaluations, resulting in $187,500 increased profits. Cooperative Extension in Haywood and Watauga Counties worked with local and state partners to provide bull breeding soundness exams, vaccinations, and other health procedures for a total economic impact of $247,000. In addition, Extension in Surry County tailored diverse educational and certification programs to help cattle producers secure an estimated $1,599,248 in added revenue based on producer evaluations, new marketing options, purchasing plans, adopted BMPs, and research projects. As a result of Extension training and outreach efforts across the state, 2,171 livestock producers adopted Extension-recommended BMPs and production changes related to quality assurance (vaccinations, castration, culling techniques, etc.), and 1,362 producers adopted Extension-recommended BMPs and production changes related to genetic improvement (AI, heifer/bull selection). **NC State Extension provided Cattle Producers with technical assistance and training on best management practices to increase the profitability of their operations.**

NC State Extension Aquaculture Agents and Specialists collaborated on the innovative development of an automatic feeding system to feed fish larvae that begin to feed soon after hatching. A prototype of this system was used in the spring of 2021, enabling efficient, highly controlled specification of feed characteristics, feed intervals, and number of daily feedings, all from an intuitive tablet-based user interface. The highly precise, consistent feeding provided by this device can help prevent fish mortalities common in both industry and research settings.

Aquaculture Agents also addressed a key health problem plaguing the development of small striped bass: oil residues from larval feed floating into culture tanks and preventing larvae from reaching surface air. Extension developed a device that floats on the surface of the water and collects the oil for periodic removal. The use of this oil skimmer is so efficient that it increased a key marker of larval health to over 95%.

Aquaculture Agents made a major contribution to aquaculture by developing a control plan for a key pathogen (streptococcus sp.), including plans for fish vaccination, disinfection, and fish health monitoring. This plan was implemented for 8 tilapia producers, some of whom reported a nearly 50% increase in fish production after implementation. This health plan will provide an estimated $1 million in increased profits for NC producers. **NC State Extension provided solution-driven research, technology, and technical assistance to aquaculture producers to empower them to make better-informed decisions.**

Briefly describe how the broader public benefited from your project's activities.

Members of the Apiculture program have collectively provided approximately 182 presentations to local and regional beekeeping groups over the last three years, resulting in over 32,000 direct contacts. During 2021, 11 scientific publications, 19, extension publications, 38 extension presentations, and 6,262 individual contacts were made. An exciting new Beekeeper Education & Engagement System (BEES) online learning community for beekeepers that includes multiple mini-courses and a 2-day in-person Intermediate BEES Academy aimed to bolster beginning beekeeper knowledge and practical skills to enhance their colony survival and beekeeping success, were developed. The apiculture program also runs the Queen & Disease Clinic to provide scientific bioassays to beekeepers on queen health and colony pathogens so that they can make real-time management decisions that affect their operations.

State- and nationwide media coverage of apiculture program activities have collectively resulted in a public increase in honey bee awareness and concern for their welfare. We conservatively estimate a 50% increase in the managed honey bee population in the state as a result of the increased interest in apiculture due to our Extension program. If honey bees account for $200 million in agricultural productivity in the state and there are now approximately 150,000 managed bee colonies in NC, then each managed hive has the potential to contribute roughly $2,000 to the state's economy. A 50,000 colony increase in the bee population, therefore, may have potentially added another $100 million to the state's agricultural economy. This is all in addition to the countless intangible impacts of the NC State Apiculture program: the Q&A session with 10 beekeepers on the steps of the Extension office because the building was locked; the hour-long phone conversation allaying the fears of a woman deathly afraid of stinging insects; the spark ignited in the young 4-H student to start his first hive. **These efforts collectively result in a tremendous impact for the general public that has a significant inherent value, even though it is impossible to place a dollar figure on it or measure its impact following any sort of objective criteria.**

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

The following professional development workshops were provided by Extension Specialists for Extension Agents in 2021 to facilitate the use and transfer of new research-based knowledge:

- Animal Ag Economic Update
- Animal Waste Management
- Forage Research Update
- Forage & Grassland Management
- Meat Rabbit Workshop for Livestock Extension Agents
- North Carolina Small Ruminant Improvement Program
- Regenerative Grazing v. Rotational Stocking

- Renewable Energy from Animal Manures
- Small Ruminant Extension Updates
- Value-Added Opportunities for NC Dairy Farms & How to Help

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

The world's population is projected to surpass 9.7 billion by 2050 and global meat production will need to increase to 455 million tons (from approximately 350 million tons today) to meet consumption demands. This is alongside a decline in farm and rangelands due to population growth and residential development, and farming's contribution to greenhouse gas emissions, fossil fuels, and other pollutants. NC State Extension is developing climate-smart agricultural practices and innovative ways to increase food animal production on less land. To support increased profitability of animal agriculture producers, NC State Extension transferred information about innovative products, novel technologies, and animal science best management practices to producers through meetings, workshops, certification programs, on farm consultations, websites, webinars, factsheets, and newsletters. Extension also helped producers development disaster, disease, and waste management plans. As a result of the solution-driven research, technology, education, and technical assistance provided to animal agriculture producers; they are making better-informed decisions and increasing profitability while decreasing the environmental impact of their operations. NC State Extension is enhancing agriculture in North Carolina that supports thriving communities and provides all North Carolinians access to safe, nutritious food.

Development of advanced phenotyping and molecular tools to improve quality traits in fruit and vegetables

Project Director
Massimo Iorizzo
Organization
North Carolina State University
Accession Number
1023945

Improved Blueberry Crop Quality through Analytical Tool Development

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

In blueberry and carrot breeding programs selection for fruit quality characteristics using traditional phenotyping methods is expensive, non accurate and non effective. To address this issue, this project aim to develop advanced DNA based and phenotyping strategies to select new cultivars of fruits and vegetables with improved quality, to support North Carolina and nationwide productions for fresh market and processing industry.

Address major bottlenecks for advancing DNA based breeding strategy to develop and implement marker assisted selection (MAS) capacity in fruit and vegetable breeding programs, to enable breeders to select and pyramid fruit and vegetable characteristics that positively contribute to fruit quality and market value. In the long term, this mission will increase production of fruit and vegetables with improved characteristics that meet the ever-changing industry, market, and consumer preferences. The project focus on blueberry and carrot and the objectives are:

- Objective 1. - Identify molecular markers associated with fruit and root characteristics and quality attributes.
- Objective 2. - Identify and characterize candidate genes controlling fruit and root characteristics and quality attributes.
- Objective 3 - Develop high-throughput molecular and phenotyping assay to select for high value fruit and root characteristics.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Major accomplishments:

Obj.1 - Identify molecular markers associated with fruit and root characteristics and quality attributes.

- Identified eighteen DNA loci for fruit quality traits in blueberry, including seven loci for fruit weight, three loci for titratable acidity (TA), five loci for pH, and three loci for total soluble solids (TSS). DNA loci for pH, Ta and TSS were stables across years, indicating that these QTL will be valuable target for developing molecular markers for these traits. Organic acids and sugar profile were assessed to understand their contribution to pH, TA and TSS. Among organic acids, citric acid was associated with TA variation, suggesting that identification of DNA loci for this organic acid could further improve accuracy for predicting TA in blueberry breeding prrograms. Evaluation of organic acids in multiple genetic stocks in ongoing.

- A novel high-throughput in vitro gastrointestinal digestion model was used to phenotype bioaccessibility of phenolics in a diverse germplasm collection representing cultivated blueberries. Results highlighted that genetic factors could control bioaccessibility of phenolics, in particular the anthocyanin which are the main phenolic compound in blueberry. Acylation of the anthocyanin, which is a chemical reaction that is usually under genetic control in plants, significantly affected anthocyanin bioaccessibility. Ongoing efforts focus on expanding this work to perform a genetic study for anthocyanin accumulation and bioaccessibility.

- Identified two DNA loci named ‘root outer phloem anthocyanin pigmentation’ (ROPAP) and ‘root inner phloem pigmentation’ (RIPAP) associated with accumulation of anthocyanin in a tissue specific manner in carrot root.

Obj 2. - Identify and characterize candidate genes controlling fruit and root characteristics and quality attributes.

- Within one of the genomic region associated with TA and pH detected in blueberry a candidate genes controlling accumulation of citric acid in other species was identified, opening opportunity for further functional characterization.

- Three candidate genes controlling tissue specific expression of anthocyanin in carrot root were identified. Two transcription factors, named DcMYB7 and DcMYB9 co-localizing in the same genomic region regulate anthocyanin accumulation in the out-phloem, while DcMYb 7 in combination with another TF named DcMYB113 regulate accumulation of anthocyanin in the inner-phloem. This results establish the foundation for ongoing work to characterize the function and the structure of these genes, in particular the DNA polymorphisms controlling the tissue specific expression of the anthocyanin.

- Over 235 anthocyanin related genes annotated in the carrot genome were integrated with 158 loci associated with anthocyanin accumulation. Over 15 anthocyanin related genes co-localized with anthocyanin loci, including genes involved in anthocyanin acylation a reaction that play an important role in anthocyanin stability for application of carrot anthocyanin as a natural colorant. Also, anthocyanin acylation affect the efficiency of anthocyanin delivery in the human diet.

- To advance identification of candidate genes controlling quality and accumulation of health related bioactive in blueberry and cranberry, and annotation of specific gene families and assembly of two new high-quality genomes were further improved and sequencing of new genomes is ongoing.

Obj. 3 - Develop high-throughput molecular and phenotyping assay to select for high value fruit and root characteristics.

- To develop molecular marker assays, identification of DNA polymorphisms tightly linked to the genes controlling specific phenotype is needed. To advance this objective, efforts to evaluate DNA polymorphisms controlling tissue specific expression of anthocyanin in carrot were initiated. An insertion in the promoter of a transcription factor was identified as causal mutation, and functional characterization is ongoing.

- A new high-throughput phenotyping system to evaluate fruit texture and appearance in blueberry was developed and is currently use to phenotype large blueberry diversity panels. The system measure 28 fruit characteristics and an automated data collection system is programmed to collect phenotypic information at harvest and after storage. The data will be used to evaluate genetics mechanisms controlling texture and shelf-life in blueberry fruit.

Briefly describe how your target audience benefited from your project's activities.

- The new high-throughput phenotyping system to evaluate blueberry fruit characteristics has been transferred to other blueberry breeding and research programs to advance selection of new blueberry cultivars with improved characteristics. Preliminary phenotypic data were used to select genotypes with superior characteristics that were used as parent for controlled pollinations.

- Two new high quality genomes for carrot and blueberry were made available to collaborators and are being used to advance genetic studies and functional characterization of gene of interest.

- Genetic and genomic resource developed during this reporting period were used as preliminary results to secure new funding by project PI as well as collaborators;

- Overall the outcomes of this project are contributing to advance the development of precision breeding in blueberry and carrot.

Briefly describe how the broader public benefited from your project's activities.

Benefits from this project to the public are projected in the long term. Consumers will benefit from access to a more stable supply of affordable and nutritious fruit and vegetable with quality characteristics that meets their preferences; this will likely translate into an increase of per capita consumption and improved human health and well-being. Extension and outreach events will contribute to enhance public understating and interest in learning and careers in plant science, and more specifically plant breeding.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

What opportunities for training and professional development has the project provided?

- Trained 2 post-docs plant genetics and genomics;

- Trained 1 Research Scientists in pre-breeding and genetics;

- Trained 1 PhD student in plant breeding, genetics and molecular biology;

How have the results been disseminated to communities of interest?

Updates about the project, and preliminary results were disseminated to the scientific community, including the U.S.- wide community of blueberry and carrot breeders and geneticists, through 11 peer reviewed publications, 16 posters and oral presentations at regional, national and international conferences (including American Society of Horticultural Science and International Vaccinium Symposium). The information was also disseminated to the broader blueberry community (producers, processors and distributors) through 2 oral presentations at commodity group meetings and two articles in trade magazines. Molecular data such as the carrot and blueberry genomes, raw sequencing data and linkage maps information were made available to the broader research community through the Genome Database for Vaccinium Species (GDV), the carrotOmics and NCBI. Outreach activities aimed at introducing students to plant science and horticulture, food science, scientific lab experience based on protocol/research were limited during this reporting period due to COVID-19 pandemic.

What do you plan to do during the next reporting period to accomplish the goals?

Obj.1 - Identify molecular markers associated with fruit and root characteristics and quality attributes.

- Phenotyping fruit characteristics for blueberry will be continued;
- Available fruit quality data for blueberry including pH, Ta, TSS and phenolic content (e.g. anthocyanin) will be used for genetic analysis
- Will initiate evaluation of plant material for carrot anthocyanin genetic study

Obj. 2 – Identify and characterize candidate genes controlling fruit and root characteristics and quality attributes

- Continue effort to sequence and annotated fruit quality related traits in new carrot and blueberry genomes
- Perform comparative transcriptome analysis to identify candidate genes associated with fruit quality traits (pH, TA, Organic acids. anthocyanin) in blueberry

Obj. 3 – Development of high-throughput molecular and phenotyping assay to select for high value fruit and root characteristics

- Validate DNA marker associated with fruit quality traits in blueberry germplasm and continue evaluation of DNA polymorphisms within candidate genes

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

In blueberry breeding programs selection for fruit quality characteristics using traditional phenotyping methods is expensive, inaccurate and ineffective. To address this issue, NC State researchers developed a high-throughput phenotyping system to evaluate fruit texture and appearance in blueberries. This system measures 28 fruit characteristics and employs an automated system to collect data at harvest and after storage. This data is crucial to evaluating the genetic mechanisms that control texture and shelf-life in blueberries. This new system has been transferred to other blueberry breeding and research programs to advance selection of new blueberry cultivars with improved characteristics. Consumers will benefit from access to a more stable supply of affordable and nutritious fruits with quality characteristics that meet their preferences. This likely increase in per capita consumption and improved human health and well-being is just one way NC State research is feeding our future.

Horticulture Plant Systems

Project Director

Meredith Weinstein

Organization

North Carolina State University
Accession Number
7000167

Recommended Best Management Practices to Increase Profitability and Efficiency of Horticulture Production

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Fruit and vegetable production plays a key role in NC's agricultural economy with farm cash receipts for horticulture totaling more than $1.4 billion in 2016. NC horticultural production includes a diverse portfolio of traditional and specialty crops including sweet potato, tomatoes, cucumbers, blueberries, strawberries, and apples. Commercial growers need resources to navigate a broad range of challenges including production costs, soil health and fertility, pest and disease management, and variety selection. Private residents also need support to cultivate home and community gardens. Public outreach efforts are crucial to ensure that residents understand how horticultural practices impact food security, economic security, and environmental health.

The world's population will surpass 9 billion by 2050. To meet consumer demand, almost 50 percent more food, feed and biofuel will need to be produced. Coupled with this, there is pressure placed on horticulture producers because of climate change, soil erosion, pests, and diseases. To meet the challenge of feeding a growing population, research-based horticulture best management practices need to be developed and adopted in the production of fruits and nuts, vegetables, floriculture, herbs, mushrooms, turf, and other specialty commodities. In addition, home gardeners and landscape professionals need to learn and adopt practices that provide sustainable landscapes, and conserve and protect environmental health.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

To support sustainable horticultural production, NC State Extension Specialists developed innovative products, technology and research-based horticulture best management practices (BMPs) through a combination of methods, including applied research, diagnostic testing, and variety performance evaluations. To support commercial growers, nursery professionals, resident gardeners, and landscape professionals, Extension promoted the adoption of BMPs through workshops, clinics, seminars/webinars, consultations, community and demonstration gardens, education and certification programs, and public outreach efforts. Extension also led research efforts to curb plant diseases and pests through improved crop management, variety selection, and pesticide management. **As a result of NC State Extension programs, 45,496 participants use Extension-recommended best management practices in landscapes, turf, and gardens, including pests (insect, weed, disease, wildlife) and soil management. In addition, 47,627 individuals gained knowledge or acquired skills related to vegetable/fruit gardening.**

- NC State Extension Specialists disseminated new horticulture information and best practices through the publication of 119 **peer reviewed factsheets** to educate Extension Agents, producers, and members of industry.

- NC State Extension Specialists maintained 29 horticulture **website portals** containing 9,356 educational **websites** that were viewed 760,712 times in 2021. 29 new pages were added along with new content added to 259 existing pages to disseminate up-to-date research-based information and best practices.

- NC State Extension Specialists produced 294 demand horticulture-related **educational videos** viewed 96,557 times.

- 35,986 individuals attended horticulture-related **training** provided by Extension Agents and 31,592 individuals attended training offered by Extension Specialists.

- 3,808 Master Gardener **volunteers** donated 158,634 hours valued at $4.1 million, reaching 77,371 NC residents.

NC State's turf insecticide efficacy program is the largest and most comprehensive in the Southeast. Extension maintains the most widely used turf entomology **Facebook page** in the world, with almost 1,000 hits per day, providing users with daily posts and weekly videos. In addition, NC State Extension maintains the **Twitter** account Dr. TurfBug, the Extension **web portals** NC Turf Bugs and Turffiles. These sites are accessed millions of times per year. More turf entomology information is disseminated through NC State Extension's program than anywhere else worldwide. This significant effort impacts turfgrass managers on a global basis.

The North Carolina **Extension Gardener Plant Toolbox** was developed and populated with detailed descriptions and photographs of 4,615 plants that grow in and around North Carolina. Users of the plant toolbox can enter the name of a plant into the search box to view the plant's profile. The toolbox features a "find a plant tool" to assist with selecting a plant. Users choose desired characteristics from an array of filters and narrow the results until their perfect plant is found. The toolbox also includes an "identify a plant" tool for someone who has a plant but does not know its name or profile. Filters are used to pick attributes of the plant, and the results display plants with those characteristics. **NC State Extension empowers individuals to make decisions by providing research-based information through websites and social media.**

In collaboration with entomologists, plant pathologists, and horticulture scientists, Extension has conducted **statewide surveys** of commercial blackberry, grape, and apple orchards to identify fungal pathogens and gather information about production factors associated with plant disease and death. Knowledge gained from these applied research projects has been communicated through 9 **presentations** to fruit stakeholders, 2 agent trainings, and 2 field days, reaching a total of 1,242 stakeholders. This research has also led to state and federal funding, including funding of a USDA-NIFA Specialty Crop Research Initiative (SCRI) proposal in 2021. **NC State Extension Specialists equipped commercial blackberry, grape, and apple producers to prevent and control plant diseases by increasing their knowledge of related production factors.**

Experiential learning can be the most impactful way to teach someone a new skill. The Sandhills AGInnovation Center's **Demo Farm** provides a venue where participants can get their hands dirty and try a new skill or project, such as pruning blueberry bushes, setting up a caterpillar tunnel, building a trellis, or harvesting sweet potatoes. The Demo Farm is managed by the horticulture agents at Cooperative Extension's Richmond County Center, who grow the crops and plan activities. **Workshops** are confidence-building exercises that provide participants with diverse levels of expertise and experience with ways to explore new ideas and opportunities, while knowing expert guidance is available to answer questions or provide help if needed. **The workshops at the Demo Farm provide inspiration and support, enabling participants to use their new skills on their farm or home garden, with the ultimate goal of supporting farmers and helping more people grow fruits and vegetables at home for themselves and their families.**

NC State Extension Specialists updated 35 tomato, cucurbit (i.e., cucumber, watermelon, squash, and pumpkin), sweetpotato, and other vegetable disease factsheets. These factsheets provide a brief synopsis that highlights the pathogen, symptoms, pathogen source and spread, and management techniques. Typically, there is a disease factsheet available for every common disease of crops produced in North Carolina, although some may be combined if the pathogen attacks more than one host. These important resources enable Extension agents to quickly diagnose problems in the field. The disease factsheets were updated and enhanced by adding helpful diagnostic tools and tips and adding additional images to help agents identify the most common plant diseases more quickly. Responses from agents have been overwhelmingly positive: 82% of agents reported that the new factsheets allowed them to better serve their clients, and almost 50% commented that the additional pictures helped with field diagnoses. **NC State Extension provided educational opportunities to facilitate the use and transfer of research-based knowledge of commercial berry, grape, tree fruit, and other fruit or vegetable producers to grow agricultural production.**

At the Western region **strawberry pre-plant meeting**, 16 growers and 9 Extension Agents learned about new strawberry varieties, weed management, plasticulture production, direct marketing, produce safety, and demonstrations of equipment used in plasticulture. Of the growers who completed the evaluation, over 82% increased knowledge in 4 out of the 5 topic areas covered. In Macon County, Extension held 7 **seminars** on strawberry, blueberry, grape, and fruit tree cultivation, providing essential information about site selection, fertility practices, plant selection, pruning, and harvesting. A total of 117 individuals attended, representing 16 NC counties, 8 states, and 3 countries. All participants reported learning something new about horticulture, and 89% expressed intention to start using best practices, including organic gardening practices. **NC State Extension transfers the latest practices to growers at workshops, seminars, and meetings.**

Briefly describe how your target audience benefited from your project's activities.

Cucurbit downy mildew is a devastating disease in cucurbit crops and the number one threat to production, especially in cucumber. The disease must be managed with frequent, expensive fungicide applications to prevent devastating yield losses. The solution-driven efforts of Extension Specialists resulted in the development of a field biosurveillance system that provides host risk and fungicide resistance information for precision management, registration of novel active ingredients for chemical

control through collaborations with fungicide companies, and release of two resistant commercial pickling cucumber varieties through collaborations with seed companies. According to the National Agricultural Statistics Service, NC has approximately 8,499 acres of cucumbers, 1,509 acres of melons, 2,514 acres of pumpkins, 2,531 acres of squash, and 5,498 acres of watermelon. Extension efforts saved growers approximately 4-6 fungicide sprays per year. Since fungicide sprays can cost about $30-$50 per acre, per application, per product, this would translate into $2.5 to $6 million in savings yearly for NC cucurbit growers alone. Extension evaluated 50 fungicide products and spray programs for effectiveness in controlling disease in tomato, pepper, and cucurbit crops, yielding insights that have been disseminated through plant disease management reports, spray guides, and crop handbooks used by over 50 growers in NC, TN, VA, SC, and GA.

Wilkes and Alexander Counties are the 2nd and 3rd largest apple-producing counties in NC, representing over 300 acres of production and over $3 million in gross sales. Local growers rely on Cooperative Extension for pest identification and management recommendations. Extension worked with commercial orchards to install 2 weather stations in orchards, monitored 13 traps in 7 orchards for 25 weeks, and ran pest and crop development models based on local scouting through the Network for Environment and Weather Applications at Cornell University using local station data. Through regular scouting and running a pest and crop load management model, Cooperative Extension was able to recommend the timing of pest management practices and pesticide applications throughout the growing season. This resulted in several benefits, including reducing applications, saving growers time and money, effectively managing oriental fruit moths to protect fruit quality, detecting peach tree borer damage and protecting unaffected trees using a rescue insecticide application, timing fireblight applications, and timing and applying the correct rate of thinner. This system of Extension-based insect trapping and scouting, coupled with weather station data, is a benefit to orchardists and is a model of how Extension can engage a group of growers while helping them be more successful. **NC State Extension provided solution-driven research and technology to empower growers to make better-informed decisions.**

Cooperative Extension in Chatham County provided three 2-hour blueberry production webinars to 527 gardeners and growers, delivering key information about blueberry cultivars, site selection, crop management, and pest and disease management. Of the participants surveyed, 100% gained knowledge of identifying and managing blueberry pests and diseases, and 93% reported improving their blueberry production through improved crop management. Cooperative Extension Agents from four of the largest wine producing counties in Western NC collaborated to provide vineyard managers timely research information via a virtual workshop and outdoor pruning demonstration. Pressing information on vineyard weed management, sour rot, spotted lantern fly, fungicide spray schedules, and industry updates were presented by NC State's Top Viticulture Specialists, along with pesticide credits. Seventy-one vineyard managers attended the virtual workshop, and 18 attended the in-person outdoor spur and cane pruning demonstration. Attendees were surveyed following the event; 74% indicated intent to implement practices presented at the workshop, and 40% estimated the information would save them up to $2,000 in management costs. **NC State Extension provided educational opportunities to facilitate the use and transfer of research-based knowledge of commercial berry, grape, tree fruit, and other fruit or vegetable producers to grow agricultural production.**

Many wholesale produce buyers require GAP certification before purchasing from farms. GAP certification is a new process for many farms, and they must remain up to date on any changes. Cooperative Extension in Surry County offered guidance on GAP certification and re-certification via phone, email, text, and farm visits. Extension also offered 2 commercial winter meetings attended by 115 growers. With Extension's help, several growers have become GAP certified over the past several years, and 2 growers were re-certified this year. For these 2 growers alone, Extension's assistance enabled the sale of $1,900,000 worth of vegetable crops. Richmond County Cooperative Extension helped the largest commercial horticulture grower in the county become GAP certified so he could more easily sell some of his 100,000 collard plants to wholesalers. With technical assistance from Extension, the farm successfully passed the GAP audit and will pursue GAP certification in other crops. **NC State Extension provided educational opportunities and technical assistance to fruit and vegetable producers on good agricultural practices (GAP) to enable farms to successfully receive their GAP certification and expand their market potential.**

Specialists conducted over 70 on-site diagnostic visits with golf course turf clients, impacting over 10,000 acres of pesticide and nutrient applications, and conducted over 60 on-site diagnostic visits with lawn care, sod farm, and landscape turf clients, impacting over 15,000 acres of pesticide and nutrient applications. As a result, turf managers make more cost-effective, environmentally responsible decisions regarding turf cultural practices, fertilizer, and pesticides. Over 5,000 turfgrass managers attended workshops, seminars, and professional talks provided by Extension. Survey results indicate that 85% of participants greatly increased their knowledge of pesticide application products and techniques, 85% will use more IPM strategies, 80% will change at least 1 management practice, and all participants indicated this knowledge will help them be more efficient and environmentally conscious in their turf pesticide and nutrient programs.

Continuing education for landscape professionals is vital to improving sustainability and reducing environmental impacts. Horticulture Agents at the Cooperative Extension Forsyth and Chatham County Centers organized a 5-part webinar series for 367 landscape and green industry professionals. Extension presented information about managing invasive species, identification and management of conifer diseases and scale insects, improving urban soils for landscape tree plantings, and using smart irrigation systems. Ninety-nine percent of participants increased their knowledge of key topics, and 80% indicated they would adopt recommended BMPs. A total of 178 continuing education credits were earned by licensed pesticide applicators, arborists, and landscape contractors. **As a leader in experiential education, NC State Extension provided turfgrass managers and landscape professionals** with **best management practices, equipping them to make environmentally and economically informed decisions.**

Briefly describe how the broader public benefited from your project's activities.

Extension Master Gardener volunteers help their neighbors understand and use research-based information and practices that decrease the misuse of fertilizers, insecticides, and pesticides in gardens, home lawns, and landscapes; increase overall food production and availability; enhance wildlife habitats, and improve human health and wellbeing. Because of the work of Master Gardeners, more people are growing food locally, planting pollinator-friendly gardens, and creating resilient landscapes that help manage stormwater runoff. In 2021, despite ongoing limitations due to COVID-19 restrictions, Extension's Master Gardener program (EMG) continued to provide exceptional horticultural education to the general public. Statewide, 77,371 residents benefitted from the program's demonstrations, community gardens, workshops, and personalized consultations. Master Gardeners reported 158,634 service hours from 3,808 volunteers for the year, valued at an estimated $4.1 million. EMG accomplished all this while continuing to support the development and launch of self-paced, non-credit online courses in plant identification and therapeutic horticulture, helping residents gain a deeper understanding of plants while exploring their capacity to enhance human health and wellness.

EMG also delivered a monthly Plants, Pests, and Pathogens webinar series in collaboration with the NC State Plant Disease and Insect Clinic. The live sessions were attended by 1,249 Extension agents and Master Gardener volunteers, and recordings attracted an additional 2,887 views on YouTube. Thanks to this webinar series, 74% of attendees increased their knowledge of pest and plant disease issues, and 72% increased their knowledge of using variety selection to sustainably reduce the impact of pests.

A few examples of the work of Extension Master Gardeners at the local level include EMG in Vance County launched a comprehensive outreach program in 2021, including a quarterly newsletter, a table at the Farmers Market, online seminars, and public demonstration gardens, reaching about 400 residents, virtually 100% of whom reported acquiring knowledge of best practices for horticulture. In addition, 300 of the participants reported implementing recommended best practices, for an estimated economic value of nearly $23,000. In Johnston County, EMG partnered with local businesses to host mobile plant clinics from April through October, providing gardening and landscaping advice to 674 residents. Assuming a value of $50 per consultation, they provided residents with $33,700 worth of expert advice. NC State's Extension **Master Gardeners connect their neighbors to horticulture through science-based education and outreach that empowers North Carolinians to cultivate healthy plants, landscapes, ecosystems, and communities.**

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

The following professional development workshops were provided by Extension Specialists for Extension Agents in 2021 to facilitate the use and transfer of new research-based knowledge:

- Abiotic Disorders
- Assessing Risks to Promote a "Food Safety Culture" in NC Produce
- Building a Plant Growth Regulator Program
- Climate-resilient Landscaping: Action Steps for Homeowners

- Disease and Insect Updates
- Google Hacks for Horticulture Agents
- Horticulture - Never Miss a Call!
- How to Implement a Master Gardener Volunteer Mentoring Program
- Interpretation of Soil Test Reports
- Introducing the Extension Master Gardener Toolkit!
- Irrigation water and produce safety
- It's Getting Hot Out There: Urban Tree Species & Climate Change
- Muscadine Pruning Workshop
- Practical Biological Control for Aphid and Thrips in Greenhouses
- Produce Handling Facility Tour and Training
- Produce Safety Alliance Training
- Rose Rosette
- Soil & Plant Tissue Sampling for Better Nutrient Management
- Soil Fertility
- Spotted Lanternfly Update & Training
- Substrate Amendments for Large Containers
- Tree Fruit Orchard Establishment - Take II
- Trends in Greenhouse Ornamental Diseases

- Turf and Lawn Update
- Vegetable IPM Field Training
- Winter Vegetable Production in High Tunnels

Websites:

- Commercial Horticulture, Nursery & Turf
- Pest Management
- Specialty Crops
- Lawn & Garden
- Extension Master Gardener

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

The world's population will surpass 9 billion by 2050. To meet consumer demand, almost 50 percent more food, feed and biofuel will need to be produced. Coupled with this, there is pressure placed on horticulture producers because of climate change, soil erosion, pests, and diseases. To support sustainable horticultural production, NC State Extension has developed innovative products, technology and research-based horticulture best management practices through applied research, diagnostic testing, and variety performance evaluations. To support commercial growers, nursery professionals, resident gardeners, and landscape professionals, Extension promoted the adoption of best management practices through workshops and certification programs, clinics, webinars, technical assistance, community and demonstration gardens, and public outreach efforts. Extension led efforts to curb plant diseases and pests through improved crop management, site selection, variety selection, and pesticide management. As a result of the solution-driven research, technology, education, and technical assistance provided to commercial horticulture producers; they are making better-informed decisions and are increasing the profitability of their operations. By attending NC State Extension's programs, 45,496 participants are using Extension-recommended best management practices in landscapes, turf, and gardens, including pests (insect, weed, disease, wildlife) and soil management. NC State Extension is enhancing agriculture in North Carolina that supports thriving communities and provides all North Carolinians access to safe, nutritious food.

Interactions and management of plant-parasitic nematodes in host plants

Project Director

Eric Davis

Organization

North Carolina State University

Accession Number

1023798

Identification of Nematode-Resistant Sweetpotato Lines

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Plant-parasitic nematodes cause an estimated $100 billion in global crop losses each year, and the development of crop varieties that are resistant to the major groups of nematodes represents a major tool to reduce nematode crop damage that's economical and environmentally friendly. This project has focused in this cycle on identifying sources of genetic resistance in different sweetpotato lines to an invasive species of root-knot nematodes called the guava root-knot nematode so that plant breeders can develop new cultivars of sweetpotatoes that are resistant to this nematode. The project also has focused in this cycle on identifying the critical molecular signals that cyst nematodes use to infect plant roots to develop new crop cultivars that are resistant to cyst nematodes.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

In one part of the project, a team of scientists from North Carolina State University, University of Missouri, Worcester Polytechnic Institute, University of Georgia, Iowa State University, and Cornell University combined their expertise and resources to investigate how a chemical signal, called a CLE effector, secreted from cyst nematodes into plant root cells upon infection, results in the formation of a feeding site within the plant roots that is required by the nematode to sustain its life cycle. Members of the team had expertise with different species of cyst nematodes that are specific pests of soybeans, sugar beets, and potatoes that enabled the team to identify a mechanism central to plant parasitism by cyst nematodes that is controlled by the CLE effectors that each cyst nematode species uses to form feeding sites in roots. A series of molecular biology experiments using the different CLE effector genes was used to determine how plant cells are affected by the CLE effectors, and the central mechanisms that are common among the activities of all the CLE effectors from the different cyst nematode species. In a second part of the project, nematologists and plant breeders at NC State University collaborated to choose a series of 91 sweeetpotato lines from different genetic backgrounds in a first effort to identify if any of the lines had genetic resistance to the guava root-knot nematode. The chosen sweetpotato lines were grown in pots in a greenhouse and infected with guava root-knot nematodes, and after 60 days the number of nematodes that successfully infected the plant roots was determined. Any sweetpotato lines that did not support reproduction of the guava root-knot nematode were considered as resistant to infection by the nematode and retested to confirm the resistance.

Briefly describe how your target audience benefited from your project's activities.

Most of the sweetpotato lines investigated by the collaborators at NC State were susceptible to infection by the guava root-knot nematode including several commercial sweetpotato cultivars like Beauregard, Hernandez, and the most widely grown cultivar, Covington. The collaborators were able to identify 19 lines of sweetpotato that were resistant to the guava root-knot nematode. All but two of the 19 lines had very strong resistance and supported almost no reproduction of the guava root-knot nematode. Among the 19 resistant sweetpotato lines were African land races like Tanzania, Bwanjule, and Dimbuka-Bukulula, a purple flesh sweetpotato cultivar called Murasaki-29, and the orange flesh cultivars Jewel and Centennial. Some of the progeny of a cross between Tanzania and Beauregard sweetpotato were also resistant to guava root-knot nematode, demonstrating that the observed resistance was genetic and providing a means to identify the resistance genes in the sweetpotato lines. The results of the project on CLE effectors from cyst nematodes conducted by a team of university investigators discovered a remarkable phenomenon. It was known that the cyst CLE effectors could mimic that activity of a normal plant signaling peptide that controls how plant cells grow and differentiate, but it was unknown how the nematodes delivered their CLE effectors to their plant cell receptor targets. The team was able to discover the cyst CLEs had a specific molecular signal embedded within the CLE effector that transported the secreted nematode CLE effector out of the plant cell so it could interact with the receptor on the plant cell surface. This embedded cellular trafficking signal was active and conserved among all the cyst nematode species investigated, and even within the CLE effectors of the reniform nematode, a related plant-parasitic nematode that forms essential feeding sites in plant roots that are similar to those required by cyst nematodes.

Briefly describe how the broader public benefited from your project's activities.

The discovery of the embedded signal in the cyst nematode CLE effectors now provides a target to disrupt the feeding and life cycle of cyst nematodes in crop plants and make the crops resistant to the nematodes. One strategy would target the embedded signal in the CLE peptide itself by using gene silencing or a targeted peptide to disrupt proper expression or cellular trafficking of the CLE effector in transgenic plants. A second strategy could identify the plant cell receptors for the nematode CLE effectors or the embedded trafficking signal and use CRISPR-Cas9 technology to modify the plant cell receptors so they don't interact with the cyst nematode CLE effectors. The discovery that the embedded molecular trafficking signal is conserved among CLE effectors of different species cyst nematodes and even the related reniform nematodes suggests that targeting this central mechanism of plant infection can provide novel resistance to these different nematodes

across many crop species. Since the soybean cyst nematode is the most destructive pathogen of soybeans in the U.S. and globally, and the potato cyst nematode is a destructive and quarantined pest in the U.S., the development of new resistant cultivars that target central mechanisms of parasitism can have dramatic economic benefits to growers and consumers alike. The sources of natural genetic resistance to the guava root-knot nematode identified in this project provide a broad base of resistance to incorporate into desirable commercial sweetpotato cultivars through conventional plant breeding. The ability to identify molecular markers and the resistance genes that are associated with this resistance provides a tool to accelerate the development of new resistant cultivars with guava root-knot nematode resistance. Since the sweetpotato lines and even the cultivars found to be resistant to guava root-knot nematodes do not have the commercial attributes that are marketable for growers and consumers, it is critical to breed the resistance identified into desirable cultivars like Covington that are currently susceptible to guava root-knot nematode. Since sweepotatoes in NC are a $400 million annual farm gate commodity and significant export crop, as well as a significant crop grown in multiple southern U.S. states and abroad, development of a commercially viable cultivar that is resistant to guava root-knot nematode would be a game changer.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

The identification of sources of resistance to guava root-knot nematode in sweetpotato have been published in the scientific journal Plant Disease under doi: 10.1094//pdis-02-20-0389-re. These results have also been presented at the annual meetings of the American Phytopathological Society and North Carolina Sweetpotato Growers Commission. The identification of the embedded cellular trafficking signal in cyst nematode CLE effectors was published in the scientific journal New Phytologist under doi: 10.1111/nph.16765. These results have also been presented at the annual meetings of the American Phytopathological Society and the International Society of Molecular Plant Microbe Interactions.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

Plant-parasitic nematodes cause an estimated $100 billion in global crop losses annually, necessitating the development of resistant crop varieties. NC State collaborated with other universities to develop new approaches for identifying resistant plants. NC State researchers identified 19 lines of sweetpotato that are resistant to the guava root-knot nematode. All but 2 of the lines had very strong resistance. The ability to identify molecular markers and the resistance genes that are associated with this resistance provides a tool to accelerate the development of new cultivars with guava root-knot nematode resistance that can have dramatic economic benefits to growers and consumers alike. Since sweetpotatoes in NC are a $400 million annual farm gate commodity and significant export crop, as well as a significant crop grown in multiple southern U.S. states and abroad, development of a commercially viable cultivar that is resistant to guava root-knot nematode would be a game changer. This project exemplifies the progress being made through the North Carolina Plant Sciences Initiative, a strategic university effort aimed at solving grand agricultural challenges.

Management of plant-parasitic nematodes

Project Director
Charles Opperman
Organization
North Carolina State University
Accession Number
1023952

Novel Plant-Parasitic Nematode Management Tools

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Plant parasitic nematodes are a cause of major economic losses to crop production. The 'Wrap & Plant' technology involves the wrapping of the planting material, i.e. vegetatively propagated tubers, suckers or stems with banana fiber paper, impregnated with synthetic pesticide (abamectin or fluopyram) or biologically based products, primarily for treatment against nematodes.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

We have completed over 60 'Wrap & Plant' field trials in yam-producing regions in Benin over a five-year period. These results provide ample data in both time and space to support efforts for a future commercial launch of 'Wrap & Plant'. Over 25 field trials for each country were conducted in Ghana and Togo with the optimized prototype, poising these countries for commercialization after a launch in Benin. We completed 4 years of field and glasshouse trials on potato in Kenya and Uganda, positioning 'Wrap & Plant' for potential commercialization there. During 2021 marketing research and surveys were initiated in all the above-indicated countries to explore factors including potential market share, cost, distribution, acceptance of the technology, potential barriers to commercialization, and any other factors our marketing consultants deem appropriate. These studies will be ongoing as we explore routes to commercialization. These plans will be developed with our consultants and collaborators in concert with national and local regulatory and governmental agencies, extension personnel, commodity groups, farmers, potential corporate partners and manufacturers, distributors, and other relevant groups identified by our regional consultants. Proof-of-concept for 'Wrap & Plant' manufacture and performance in Africa was achieved during the previous period and paves the way for future translation to African manufacture of 'Wrap & Plant'. Laboratory analysis of banana paper manufactured in Uganda with locally available material has demonstrated properties like our 'Wrap & Plant' product and demonstrates the ability to manufacture in Africa as envisaged. Paper manufacturing was substantially advanced toward a first-generation product and will provide an optimized prototype and scale-up process for manufacture of 'Wrap & Plant' in Africa, an essential component for future translation to commercialization through African partner companies. Ongoing research will provide vital data to ensure sustainability and successful utilization of 'Wrap & Plant' and potential new approaches to applications of this technology for nematode management by smallholder farmers, as well as growers in developed regions including the USA.

Briefly describe how your target audience benefited from your project's activities.

Development and deployment of this product will substantially improve plant parasitic nematode management in an affordable and sustainable manner, resulting in increased yields, food production, and incomes.

Briefly describe how the broader public benefited from your project's activities.

We have developed a technology to deliver microdosages of nematicides to control plant-parasitic nematodes. This will result in greatly reduced amounts of chemical being applied to soil, less environmental impact and residue, fewer non-target effects, and higher quality produce. Adoption of this technology will also have substantial positive economic impacts for communities.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

Plant-parasitic nematodes cause major crop losses. NC State researchers have completed over 60 field trials of a technology that involves wrapping planting material with banana fiber paper containing synthetic or natural pesticides. These trials were conducted over a 5-year period in Benin, followed by an additional 50 field trials in Ghana and Togo with an optimized prototype, positioning these countries for commercialization of the technology. Researchers also completed 4 years of field and glasshouse trials on potato crops in Kenya and Uganda. This proof-of-concept paves the way for future African manufacturing of this technology and has the potential to increase yields, food production, and incomes. NC State researchers also developed a technology that delivers microdosages of nematicides to control nematodes, which can greatly reduce application volume, causing less environmental impact and residue, fewer non-target effects, and higher quality produce. Adoption of this technology will also have substantial positive economic impacts for communities. This is just one example of how NC State is growing the future of agriculture in NC and beyond.

Pasture Pest Management: Advancing the IPM tool box

Project Director

David Watson

Organization

North Carolina State University

Accession Number

1024019

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

The aim of this project to advance new tools for the management of pasture pests targeting a new invasive tick in NC, and traditional pest flies including the face fly, horn fly and stable fly. The first goal of the project is to assist in the national effort to contain the Asian longhorned tick and mitigate its' impacts on the cattle industry. The remaining goals of this project is to develop a better understanding of pest management issues facing the dairy industry regionally by using a survey instrument to identify regional pest and disease problems. We also expand the scope of exiting technology making the vacuum fly trap more versatile and efficient. The trap is an efficient tool for fly management on cattle without the use of insecticides.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Major Goals of the project

Objectives

1. Containment and mitigation of Asian longhorned tick in North Carolina.
2. Study of the Appalachian dairy industry on pest and disease impediments regionally.
3. Dispersal potential of horn fly, face fly and stable fly.
4. Develop a vacuum fly trap amenable to both dairy and beef cattle production.

What was accomplished under these goals?

Objective 1. Containment and mitigation of Asian longhorned tick in North Carolina.

The invasive tick *Haemaphysalis longicornis*, the Asian longhorned tick (ALT) was introduced to the US in 2010. This three-host tick has a wide host range, capable of feeding on different animals for each of the three life stages, larva, nymph and adult. All three life stages may be found on host animals or in the environment. The tick has expanded its range from 12 states in 2019 to 17 states today. Virginia has been most impacted by the tick, followed by West Virginia and North Carolina. Currently the tick has been found in 21 of 100 North Carolina Counties, nearly all in the mountains and piedmont region of the state.

Asian longhorned tick investigations were conducted in NC counties where incidents involved cattle. Environmental sampling using the standard tick flagging/dragging technique was routine. When ticks were present, sampling often produced several hundred adults, nymphs and larvae. When tick numbers are great, above 1000 per 25-30 meter drag, the landowner was provided with options that included the treatment with a labeled insecticide for tick control in pastures. Pasture treatments typically kill the ticks present at the time of application providing that they come in contact with the active ingredient. Precautions to prevent the pollinator and water source exposures were required.

As expected no ticks were found in the pasture three weeks post treatment. However, at 6 weeks post treatment, 4979 larval ticks were collected in the pasture but no adults or nymphs, indicating the pasture treatment did not kill the eggs. Larvae in the pasture had hatched from eggs present in the thatch. A second environmental treatment was applied to the pasture targeting the larval ticks. No ticks were observed in the pasture until springtime when 11 nymphal ticks were collected.

On-animal treatments options include using a spray, pour-on or self-application devices such as a backrubber treated with a commonly used insecticide for controlling ectoparasites including ticks. Here, cattle were forced to use the backrubber daily. On animal treatments were maintained throughout this period and cattle remained tick free during the period.

Objective 2. Study of the Appalachian dairy industry on pest and disease impediments regionally. This is a USDA OREI funded collaborative project between NCSU CALS Department of Animal Science, and CVM Department of Population Health and Pathobiology. The proposal seeks to improve systems-based animal production, animal health, and pest management practices while enhancing economic viability.

Surveys were sent to 1500 dairy producers in six states. We received responses from 4.2% of the stakeholders comprising with 84% from conventional dairies and 16% organic. Respondents indicated that insects were problematic for their herds and leading to a concern for cow comfort. Flies were linked to a perceived issue with pinkeye and mastitis, and likely causes a reduction in milkproduction. Most producers rely on insecticides to manage pests of cattle.

Objective 3. Dispersal potential of horn fly, face fly and stable fly. Nothing to report

Objective 4. Develop a vacuum fly-trap amenable to both dairy and beef cattle production. The vacuum fly-trap is proven technology in pasture fly management for dairy cattle. The trap relies on electric power to remove flies from dairy cattle during daily milking procedures. The reliance on electricity limited the potential use of the trap. We converted the trap to propane to allow for use in pasture settings or any place where electricity was not available. Modifications include state of the art solar chargers, modified propane engine, microprocessor controllers and proximity sensors. The modified trap effectively reduced the number of flies on cattle to below threshold levels (200 flies per animal) within a month without the use of insecticides.

Briefly describe how your target audience benefited from your project's activities.

Information developed from the Dairy survey were incorporated into research and extension proposals for extramural funding. Additional information from the survey are included in educational materials for producers on the efficacy of commonly used insecticides and their application. Training opportunities provide stakeholders of other pest management options available to them.

Briefly describe how the broader public benefited from your project's activities.

Every extension meeting and presentation has included updates on the distribution and biology of Asian longhorned tick. My intent is to alert the public to the presence of this tick, how to collect samples and have them officially identified and included in the USDA database. Additional extension presentations to cattle producer organizations have targeted fly management practices and new innovative management tools.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Asian longhorned tick surveillance will continue for 2022. The season of ALT activity runs from March to November annually. Evidence suggests that cultural control practices that include mowing pastures regularly may reduce the need for environmental treatments. A comparative study of the passive walk through fly-trap and the vacuum fly trap will be conducted in the upcoming year. This project is under development on a NCDA dairy operation in eastern NC that serves as a showcase of research and extension for the state. Additional work on the flight time, duration and dispersal potential of flies will be conducted.

Participant FTE for the reporting period.

Scientiste= 0.3 Undergrade= 0, Graduatee= 0, Postdoc = 0

Technicale= 0.3

Computed totale= 0.6

2021 Publications

Brewer, G.J., Boxler, D.J., Domingues, L.D., Trout Fryxell, R.T., Holderman, C., Loftin, K.M., Machtinger, E., Smythe, B., Talley, J.L. and Watson, W., 2021. Horn Fly (Diptera: Muscidae)—Biology, Management, and Future Research Directions. *Journal of Integrated Pest Management*, *12*(1), p.42.

Trout Fryxell, R.T., Moon, R.D., Boxler, D.J. and Watson, D.W., 2021. Face Fly (Diptera: Muscidae)—Biology, Pest Status, Current Management Prospects, and Research Needs. *Journal of Integrated Pest Management*, *12*(1), p.5.

Chen, K., J. M. Deguenon, G. Cave, S. S. Denning, M. H. Reiskind, D. W. Watson, D. A. Stewart, D. Gittins, Y. Zheng, X. Liu, C. S. Mouhamadou and R. M. Roe. 2021. New thinking for filth fly control: residual, non-chemical wall spray from volcanic glass. Med. Vet. Entomol. doi: 10.1111/mve.12521

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

The NC cattle industry is plagued by pasture pests, some of which are invasive and demand heavy insecticide control measures, leading to the need for further precautions to protect pollinators and water sources. NC State researchers converted an electric vacuum fly-trap into a propane fueled model to enhance ease of use in dairy cow pasture settings or in any setting in which electricity is not available. The modified trap effectively reduced the number of flies on cattle to below threshold levels (200 flies per animal) within a month without the use of insecticides. Training and presentations were provided to cattle producers on novel fly management practices and new innovative pest management tools available to them. NC State's integrated research and extension programs include ongoing efforts to grow the future of agriculture production with innovative, efficient, cost-effective, and environmentally friendly solutions.

Plant Production Systems

Project Director
Lauren Hargrave
Organization
North Carolina Agricultural and Technical State University
Accession Number
7001857

Season Extension of Vegetables and Small Fruits

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Small, limited-resource farmers in North Carolina face many challenges in producing and marketing specialty crops such as vegetables and small fruits, which leads to less desirable economic returns. Low-tech, low-input season extension tools such as high tunnels, often cost-shared by the USDA's High Tunnel System Initiative, have been proven effective in helping small farmers extend their growing, harvesting, and marketing seasons to increase their profitability.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

N.C. A&T county Extension agents helped small farmers produce specialty crops by providing research-based information and recommendations. The agents received training and applied research and demonstration results from N.C. A&T Extension specialists to equip themselves with the latest research and practices to help the target audience: Small, limited-resource farmers. In 2021, demonstration and applied research projects with warm- season vegetables included tomatoes (slicer and cherry), bell peppers, eggplants, and English cucumbers. Cold season vegetable projects conducted in six high tunnels focused on bok choy, lettuce, Swiss chard, collard greens, kale, broccoli, cauliflower, Brussel sprouts, beets, carrots, radish, turnips, and kohlrabi. Data on yields and produce quality were collected and the results were summarized and shared with farmers, Extension agents, and other horticultural professionals. COVID-19 affected the labor management of these projects, but project outcomes were still sound.

Briefly describe how your target audience benefited from your project's activities.

Small, limited-resource farmers benefited from this program by adopting newly-learned technology skills into their farming practices. Extension agents benefited from the program by becoming equipped with the latest research-based information and technology that helped the audiences they serve in multiple counties.

A total of 298 participants attended outreach events, not including phone and email contacts. Our previous research confirmed the net income of high tunnels at $8 to $10 per square foot from a warm-season crop through a cool-season crop. Assuming that 50% of event participants utilize a typical 30-foot by 96-foot high tunnel on their farm, the added income for farmers is estimated to be between $3.4 million and $4.3 million.

We conducted evaluations on the High Tunnel Winter Vegetable Field Day training. The return rate of the surveys was 70%. Of the surveys returned, 100% of participants agreed (2) or strongly agreed (24) that the content was valuable. Additionally, 100% of participants stated that they learned new information and would apply what they learned on their farms.

Franklin County Cooperative Extension worked with the Natural Resource Conservation Service (NRCS) and Cooperative Extension at N.C. A&T to design a high tunnel program. The program was virtual because of COVID-19 and included a series of educational sessions focused on high tunnel production topics, including high tunnel cost-share funding (USDA NRCS), high tunnel soil health (Dr. Janel Oheltz), high tunnel irrigation (Colby Griffin), and intensive high tunnel management (Dr. Sanjun Gu). Fifteen people participated in the programs. As a result of attending the Virtual High Tunnel Series, 50% of participants said they were a lot more knowledgeable about high tunnel soil health and 50% said they were moderately more knowledgeable compared to before the program. Prior to the program 50% of participants stated they did not know anything at all about high tunnels, and the other 50% said they knew little. The same was true regarding irrigation, with 50% saying they knew a great deal more after the program than they did when they started.

In Avery County, farmers attended a two-hour tour of a local vegetable grower's high tunnel. The tour focused on producing vegetables in a high tunnel. The group discussed fertility and water requirements, and regulating temperatures in a protected environment.

In Union County, eight one-hour monthly meetings on high tunnel production were held with a total of 107 attendees.

Briefly describe how the broader public benefited from your project's activities.

N/A

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Outreach Activities

- High Tunnel 101. AgriShop Academy-Western Region (virtual). Feb.22. 30 participants.
- High Tunnel 102. AgriShop Academy-Eastern Region (virtual). Feb. 26. 35 participants.
- Winter Vegetable Production in High Tunnels of One- or Two-Layers of Plastic Covers. 2021 Small Farms Week (virtual). Mar. 23. 125 participants.
- 2021 Virtual Strawberry School. University of Arkansas Extension. Aug. 28. 45 participants.
- Fall High Tunnel Series—Intensive High Tunnel Management (virtual). Nov. 2. Franklin County Extension Center. 12 participants.
- High Tunnel Winter Vegetable Field Day: high tunnel vegetables; high tunnel structure and types (in-person). Dec. 7. N.C. A&T University Farm. 51 participants.

- High Tunnel Farming Unboxing. https://youtu.be/5rS_ovPGoHQ. Dec. 21. - 223 views

In-Service Training (Virtual)

- Vegetable Crop Production for Urban Agriculture: Winter Production with Cruciferous crops. March 2&3. 34 participants.

- Extension Horticulture Project and Publication Update. 2021 A&T Fall Staff Institute. Aug. 10-13. 21 participants.

- High Tunnel Winter Vegetables. 2021 State Extension Conference. Oct. 25-27. 37 participants.

Peer-reviewed Extension Publications

- A comprehensive high tunnel farming guide (64 pages) was published in October. High Tunnel Farming. ANR-21-01, A&T Extension.

- Use of Tunnel Systems. Chapter 22 of the Southeast Regional Strawberry Plasticulture Production Guide was drafted and submitted for editing in November.

Pee-reviewed Journal Publications

- Gu, S. & Rana, T. S. (2021). Growth, yield and fruit quality of organic day-neutral strawberry in field and low tunnel settings in the southeastern United States. *Acta Hortic, 1309*, 447-456. https://doi.org/10.17660/ActaHortic.2021.1309.64.

- Gu, S. & Ballard, A. (2021). Low tunnels increased early-season yield of organic June-bearing strawberries in southeastern United States. *Acta Hortic,* 1309, 457-462. https://doi.org/10.17660/ActaHortic.2021.1309.65.

Pee-reviewed Abstracts

- Kafle, A., Gu, S., & Yang, G. (2021). Growth, yield, and fruit quality of cucumber in high tunnels with single- or double-layer plastic cover in North Carolina. *HortScience 56*(9) Supplement S8 (abstr).

- Gu, S., Kimes, J.E.& Moffitt, Q. L. (2021). Over-Winter Swiss chard yields the same in high tunnels with one or two plastic covers in the piedmont of North Carolina. *HortScience 56*(9) Supplement S47-48 (abstr).

- Gu, S., Kimes, J. E., & Moffitt, Q. L. (2021). Collard greens thrive winter in high tunnels in North Carolina. *HortScience 56*(9) Supplement S198-199 (abstr).

- Kafle, A., Gu, S., & Yang, G. (2021). Effect of single or double plastic covers of high tunnel on growth, yield, and fruit quality of tomato. *HortScience 56*(9) Supplement S251-252 (abstr).

Closing Out (end date 09/07/2023)

Small Grain Breeding Investigations

Project Director

Joseph Murphy

Organization

North Carolina State University
Accession Number
1024018

Value-added small grain breeding lines

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

The average life of a small grains cultivar in the southern United States is five seasons. The demise usually results from changes in the biotic stresses and non-competitive yield. We are using proven, conventional methods for developing superior varieties of wheat, oats, triticale and rye combined with cutting edge approaches that speed the process and make it more efficient. Cutting edge approaches utilize genomic selection whereby DNA sequences of plants are utilized to predict how individual plants will perform before that are actually evaluated in the field. We are investigating the genetics of novel resistances for Fusarium Head blight (FHB) and Hessian fly in wheat.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Cultivar Development: 665 F2 and F3 bulks (total) were advanced during 2020-21 utilizing mass selection. Almost all crosses contained one or more parents exhibiting pertinent disease and insect resistances. Approximately 26,000 head rows in the F4, F5 and F6 generations (total) underwent selection using the pedigree method. We cooperated in numerous uniform performance nurseries of advanced generation lines with multiple public and private programs, but primarily with the seven state SunGrains breeding cooperative.

Significant Results: Three wheat lines and two oat lines are undergoing the cultivar release process. The wheats contain resistance to scab, powdery mildew, leaf rusts, Barley Yellow Dwarf Virus and Hessian fly combined with superior yield, test weight and quality.

I coordinated the Southern Uniform Winter Wheat Scab Nursery. The nursery evaluated 42 advanced generation lines from five public and one private company breeding programs for resistance to FHB at up to eight locations. I called for entries and distributed seed to cooperators in September 2020. I collated and summarized data and published a report on the USWBSI website.

Significant results: https://scabusa.org/pdfs_dbupload/suwwsn21_report.pdf. The Southern Uniform Scab Nursery provides public and private sector breeders with multi-environment evaluations of FHB resistance in advanced generation breeding lines compared with the resistant check varieties. This speeds the release of varieties because scab resistance data are laborious to obtain.

In cooperation with my Research Associate, Jeanette Lyerly and Dr. Gina Brown Guidera USDA-ARS, we ran the Genomic Selection activities in for the seven university SunGrains breeding cooperative.

Significant Results: Genomic predictions for numerous agronomic traits were distributed to breeders for over 3,000 advanced lines in March 2021 prior to field selection. Correlations between predicted and observed measures for scab resistance ranged as high as 0.67. Our five years of applied experience with genomic predictions for scab resistance and yield strongly suggest that the initial selection for both these key traits can be made based on genomic predictions rather than expensive field evaluations without detrimental impact on a program.

Scab Research. NC13-20076 has demonstrated high levels of FHB resistance. Nevertheless, it does not contain previously identified FHB resistance QTL. A population of 187 lines from the cross of a susceptible line and NC13-20076 was phenotyped in misted and inoculated nurseries in six environments. Visual ratings of *Fusarium* damage on heads (VR) were recorded in field; percent *Fusarium* damaged kernels (FDK) and deoxynivalenol (DON) accumulation were recorded post-harvest. Interval mapping and multiple QTL mapping were performed on each environment trait combination. Eight QTL related to disease traits were consistently identified across QTL scans.

Significant results: The genetics of resistance in this line, which is being widely used as a parent, provides breeders the wherewithal to select for the resistance genes being provided by this paren. This makes the variety development process more efficient.

Hessian fly research: Genetically resistant varieties are the most effective method of Hessian fly management. Southern U.S. wheat breeders have observed cultivars exhibiting a “Field Tolerance” to Hessian fly that acts like horizontal resistance and is not detectable by greenhouse assay. The field tolerant “LA03136E71” and susceptible cultivar “Shirley” were crossed to develop a population of 200 random lines. Over three years in North Carolina, field grown plants evaluated for the total number of tillers, number of infested tillers, and total number of larvae/pupae. Interval mapping identified a single large effect QTL on the distal short arm of chromosome 7D for all environment-trait combinations.

Significant results: This is the first time that solid genetic evidence has been reported concerning a field tolerance gene. This will significantly improve breeders’ efforts to integrate this long term, sustainable resistance, into US varieties.

Briefly describe how your target audience benefited from your project's activities.

Breeders Seed of three competitive wheat lines with moderate FHB resistance, NC11541-14, NC12164-200T, and NC18-16900 produced for probable release in 2022. Breeders Seed of three competitive oat lines, NC12-3753, NC17-6440 and NC19-3541 produced for probable release in 2022. The Uniform Winter Wheat Scab Nursery data are key pieces of information utilized to justify the release of new wheat varieties. Identification of KASP markers for novel QTL associated with scab and Hessian fly resistances greatly improves efficiencey of the wheat variety development process.

Briefly describe how the broader public benefited from your project's activities.

A sustained production of superior wheat and oat varieties improves farm income, food and feed availability. The reduced use of pesticides on genetically resistant varieties is beneficial to the environment, reduces input costs and should reduce food and feed prices.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

The average lifespan of a small grains cultivar in the southern US is 5 seasons. NC State researchers used proven methods to develop superior varieties of wheat, oats, triticale, and rye combined with cutting-edge genetic approaches that support more efficient development of new varieties with characteristics such as disease and insect resistances. In 2020-21, researchers collaborated with public and private partners to develop three wheat lines and two oat lines that are undergoing the cultivar release process. The wheats contain resistance to scab, powdery mildew, leaf rusts, Barley Yellow Dwarf Virus and Hessian fly, combined with superior yield, test weight and quality. In addition, NC State researchers have presented, for the first time, solid genetic evidence of a Hessian fly field tolerance gene, which will significantly improve breeders’ efforts to integrate long-term, sustainable insect resistance into US breeding lines. A sustained production of superior wheat and oat varieties improves farm income, food and feed availability. The reduced use of pesticides on genetically resistant varieties is beneficial to the environment, reduces input costs and should reduce food and feed prices. These are the kinds of results made possible through funding by USDA-NIFA, USDA-ARS, North Carolina Small Grain Growers, Inc., and North Carolina Foundation Seed Producers, Inc.

Weed Management in Nursery Crops and Landscapes

Project Director
Joseph Neal
Organization
North Carolina State University
Accession Number
1023277

Development of an automated/ mechanized system for directed herbicide applications in container nursery crops

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Labor availability and costs are of high concern to nursery crop producers. Despite the availability and utilization of numerous herbicides, weeds continue to emerge. No selective postemergence herbicides are available to control the dominant weed species; therefore, growers must rely on hand removal. In fact, the recommended grower practice is to hand

weed pots ever 2 to 3 week. As an alternative to hand weeding, a prototype spray system has been developed that can make directed applications of herbicides to the surface of the container substrate

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

In 2021 experiments were conducted to evaluate the safety and efficacy of postemergence herbicides applied with this prototype sprayer. The postemergence herbicides, diquat, glufosinate, and flumioxazin were applied as directed sprays to container grown rose (*Rosa* X 'Knockout Red'), hydrangea (*Hydrangea macrophylla*) and arborvitae (*Thuja* X 'Green Giant"). Broadspectrum residual herbicides known to cause crop injury from broadcast applciations were also applied using the protoype sprayer. Weed control of common nursery weeds was evaluated in separate containers. Both diquat and flumioxazin controlled spurge (*Euphorbia maculata*) and bittercress (*Cardamine flexuosa*) nearly 100%. Glufosinate controlled spotted spurge but was ineffective on flexuous bittercress. When applied with the prototype sprayer, crop injury was eliminated or greatly reduced compared to broadcast (over the top) applications. Hydrangea plant sizes were reduced by all POST treatments with flumioxazin causing more stunting than diquat or glufosinate.

Briefly describe how your target audience benefited from your project's activities.

Additional engineering development will be required before a practical system is available for grower implementation. However, this research demonatrated proof-of-concept that postemergence weed control in container nursery crop production is possible using agrichemical tools.

Briefly describe how the broader public benefited from your project's activities.

Improved weed management will impact producers of nrusery crops, helping to maintain the economic viability of this economically important industy and employer.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Results will be reported to nursery crop producers via a webinar in 2022 and presentations at the national conference of American Hort.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

Weed control is an essential but costly component of any nursery crop production or landscape maintenance system. Despite the availability of numerous herbicides, there are few effective weed control options for some crops and weeds of increasing importance. To address this issue, NC State researchers have developed a prototype automated spray system for directed herbicide applications in container nursery crops. Ongoing testing is underway to evaluate the effectiveness of this sprayer, and results will be reported to nursery crop producers via a webinar in 2022 and presentations at a national American horticulture conference. In addition, researchers are conducting weed control experiments in the field to evaluate methods for combating common nursery and landscape weed species, including species for which limited research data are available. Researchers are also evaluating the safety of newly registered and experimental herbicides on common nursery crops, with a focus on evaluating the safety of herbicides and herbicide/plant combinations for which limited data are available. For example, researchers have provided data to facilitate registration of herbicides to protect Southern Appalachian Christmas tree production from herbicide-tolerant weeds. In this way, NC State is growing the future and preserving the profitability of NC's agricultural economy.

Refining the recommendations of fertilizers based on soil analysis and plant tissue analysis in North Carolina

Project Director

Luciano Colpo Gatiboni

Organization

North Carolina State University

Accession Number
1021547

Enhanced Efficiency of Fertilizer Recommendations

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Recommendations of fertilizers need to be constantly updated due to crop yield increases, use of new crop varieties, changes in soil management and practices, development of new fertilizer sources, and introduction of new crops species in the local agriculture. This project is using long-term soil fertility trials and on-farm trials to refine the recommendations of fertilizers for NC crops. The average soil fertility and soil health status has been measured in samples from agricultural counties of NC. This information is used as background information to propose changes in the fertilizers recommendations for NC.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Our activities collected data enough to support a decision of reducing the rate of phosphorus (P) recommended for corn, soybean, and wheat in North Carolina. Until July 2021, phosphorus fertilizers were recommended for any field with P index below 65. After July 2021, no phosphorus fertilizers are recommended for fields with P index higher than 50. It was estimated this modification would save 5.5 million pounds of P2O5 (P fertilizer) per year in North Carolina.

Briefly describe how your target audience benefited from your project's activities.

Our stakeholders, especially farmers, benefit from my project because we are helping them to save dollars in their fertilizer program. Reducing unnecessary nutrient application will not affect negatively their yields, will make their activity more profitable, and will reduce the footprint of agriculture in the environmental quality.

Briefly describe how the broader public benefited from your project's activities.

The broader public benefited from our program because we are producing agricultural goods with less fertilizer inputs and with less environmental impact.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

The results have been disseminated in extension meeting with farmers and training of extension agents. Results also have been presented in technical meetings and congresses.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

Fertilizer recommendations must be constantly updated due to crop yield increases, crop variety selection, soil management, and fertilizer sources. NC State researchers use long-term soil fertility trials and on-farm trials to refine recommendations. Data gathered at NC State provided support for a decision to reduce the rate of phosphorus (P) recommended for corn, soybean, and wheat crops in NC, saving an estimated 5.5 million pounds of P fertilizer annually. This data was disseminated in Extension meetings with farmers, training of Extension agents, technical meetings, and technical congresses. As NC State researchers discover game-changing insights, NC State Extension delivers research-based knowledge to all North Carolinians, helping to transform science into everyday solutions that make agriculture production more profitable and reduce the negative impact of agriculture on environmental quality.

Characterization of tomato infecting viruses and utilizing Barley yellow dwarf virus as an expression vector

Project Director
Timmy Sit
Organization

North Carolina State University
Accession Number
1020457

Improved screening technique for key tomato pathogen

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Tobamoviruses that infect tomato plants are typically seed transmitted (seedborne or true seed infection). Too often, symptoms of virus infection don't manifest themselves until later in the growing season leading to yield losses along with the perpetuation of infected, asymptomatic breeding material. We've developed a simple PCR screening assay for tomato seeds for the tomato breeders to ensure their seed stocks are virus free. This procedure was developed due to an outbreak among tomato plants in the NCSU tomato breeding program.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

The test that we developed was shared with the tomator breeders and successfully utilized for seed lot testing. Unfortunately, due to the COVID-19 pandemic, a large majority of the field trials was put on hold and thus, the breeders didn't really need to use our test currently.

Briefly describe how your target audience benefited from your project's activities.

Tomato breeders were made aware of the hidden presence of virus in seed stocks as a result of the PCR assay. This allowed them to take measures that would either chemically neutralize the virus in the seeds or avoid using particular batches of infected seeds for breeding purposes.

Briefly describe how the broader public benefited from your project's activities.

By ensuring clean tomato breeding seed stocks, the general public will have more confidence in the health/cleanliness of newly released tomato varieties from the NCSU breeding program.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

As mentioned above, the COVID-19 pandemic has severely curtailed the need for our services. Nonetheless, I was able to train 2 senior undergraduate students on basic plant virology and general molecular biology techniques as part of student research projects. As a result of the training they received, one of the students was confident enough to be hired and excel in research in another lab at NCSU. Furthermore, that student has been accepted to graduate studies at the University of Georgia (among several where she was offered admission).

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

Tobamoviruses infect tomato plants and are typically transmitted via infected seeds. The symptoms of this viral infection often don’t manifest until later in the growing season, resulting in yield losses and further spread. To address this challenge and mitigate a viral outbreak among tomato plants NC State researchers have developed a simple screening technique to help tomato breeders ensure their seeds are virus free. This test has been shared with tomato breeders and successfully used for seed lot testing, allowing them to take measures to chemically neutralize or discard infected seeds. By ensuring clean tomato breeding stocks, the general public can have more confidence in the health and cleanliness of NC State’s newly released tomato varieties. This project’s results exemplify the progress being made through the North Carolina Plant Sciences Initiative, a major interdisciplinary effort designed to address the biggest challenges facing agriculture today.

Gut Health and Prevention of Antibiotic Resistant Foodborne Pathogens in Poultry - Alternatives to Antibiotics

Project Director
Hosni Hassan
Organization
North Carolina State University
Accession Number
1020407

Alternatives to the use of antibiotics in poultry production

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Food-borne infections following the consumption of poultry meat and egg products contaminated with Salmonella enterica is a major public health concern. There is an increased concern of antibiotic resistant superbugs due to the use of antibiotics in animal feed. Thus, in the current era of "No-Antibiotic-ever" in farming, there is a huge interest in finding alternatives to antibiotics. Our project is focused on improving the gut microbiota by natural means in order to provide protection against colonization by invasive antibiotic resistant pathogenic organisms.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

We used a multiprong approach to reduce antibiotic resistant *Salmonella* in poultry

1. We found that treating of day-old chicks with the prebiotic (GOS) or with our safe *Salmonella* vaccine affected the chick's gut microbiome and when challenged with virulent wild type *Salmonella* resulted in 2- and 3-log reduction in *Salmonella* counts, respectively.

2. We also found that using essential oils (e.g., cinnamaldehyde and carvacrol) inhibited the growth of antibiotic resistant *Salmonella* and *E.coli* and inhibited bacterial conjugation (i.e., prevented the transfer of antibiotic resistant markers between the strains, and had no effect on the good probiotic bacteria normally found in the chicken's gut.

3. We identified and tested natural biochemical compound generated by macrophages during encountering infection by pathogenic bacteria (e.g., *Salmonella*), and found them to be effective in killing the pathogen regardless of antibiotic resistance status.

4. Work is in progress to identify other natural products and/or by-products that can inhibit the transfer of antibiotic markers and prevent the growth of antibiotic resistant *Salmonella* as well as other bacterial pathogens in poultry.

Briefly describe how your target audience benefited from your project's activities.

1. **The public at large and specifically young people (4-H)** By learning about the scope of the problem at a younger age helps in disseminating the knowledge to the next generations.

2. **The poultry farmers and poultry meat processors.** This will give them new tools to combat this social and economic problem.

3. **Consumers**. They will rest assure that their food supply is safe.

4. **Legislators.** They need to know the fact so they can allocate the budget wisely to so this critical problem.

5. **The Scientific community**. They will learn new and innovative approaches to science.

Briefly describe how the broader public benefited from your project's activities.

The public will benefit from the knowledge by being assured that their food supply is free of pathogenic bacteria and specifically free of antibiotic resistant bacteria that can transfer the resistance markers to other organisms. Thus, they will rest assured that if they get sick their treating Doctor can find the appropriate antibiotics needed to improve their health.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

- **Describe and explain any major changes or problems encountered.**

There is no major changes or problems encountered.

- **Opportunities for training and professional development provided**

We trained 4 undergraduate students in food safety and made them aware of the problem of the spread of antibiotic resistance traits in the food chain and how it will cause problems in the future finding antibiotics to treat serious illnesses in humans.

- **How results have been disseminated**

The following manuscripts were published:

- Troxell, B., M. Mendoza, R. Ali, M.D. Koci, and **H. Hassan** (2020). **The Attenuated *Salmonella enterica* serovar Typhimurium, strain NC983, is Immunogenic and Protective Against Virulent Typhimurium Challenge in Mice. Vaccines. 8 (4), 646. (doi: 10.3380/Vaccines 8049646)**

- Mendoza, M., R. Ali, N. Roberts, L. Boop, K. Bedell, B. Rhew, **H. Hassan,** A.M. Azcarate-Peril, and M. Koci (2021). **Giving Good Bacteria to Chickens to Keep Humans from Getting Sick. *Front. Young Minds 9:611302*. (doi: 10.3389/frym2021)**

- Trent Peacock and **H. M. Hassan (**2021). **Role of the Mn-catalase in Aerobic Growth of *Lactobacillus plantarum* ATCC 14431. Applied Microbiology 1(3) 615-625. (doi: 10.3390/applmicrobiol 1030040)**

What to be done in the next reporting period?

Finish and published the works on essential oils and continue the studies on other natural products that can be used to combat the spread of antibiotic resistant pathogens through the food supply.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

Salmonella infection following consumption of contaminated poultry meat and egg products is a major public health concern, which is exacerbated by increasing antibiotic resistance. NC State researchers are addressing this challenge by developing new ways to naturally enhance poultry gut bacteria to defend against antibiotic resistant germs. Researchers have discovered that treating day-old chicks with a specific prebiotic or with an NC State-developed Salmonella vaccine significantly reduced Salmonella growth, and the use of certain essential oils also inhibited the growth of antibiotic resistant Salmonella and E. coli, and it prevented the transfer of antibiotic resistance among different strains of bacteria, all while having no impact on beneficial gut bacteria. Researchers also identified and tested natural compounds produced by immune system cells and found them to be effective in destroying germs regardless of antibiotic resistance. As a result of this work, the public can be assured that their food supply is free of pathogenic bacteria and specifically free of antibiotic resistant bacteria that can transfer the resistance markers to other organisms. Thus, they can rest assured that if they get sick, their treating doctor can find the appropriate antibiotics needed to improve their health. This is just one example of how our world-leading faculty are at the forefront of innovation and discovery in animal health.

Mitigating Intestinal Salmonella spp. Colonization in Poultry through Phytobiotics

Project Director
Yewande Fasina
Organization
North Carolina Agricultural and Technical State University
Accession Number
1019920

Mitigating Intestinal Salmonella spp. Colonization in Poultry through Phytobiotics

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

There is increasing restriction in the incorporation of antibiotics into poultry feed to control intestinal pathogens such as Salmonella spp. because, their use has promoted emergence of drug-resistant bacteria. This study aims to evaluate the efficacy of ginger root extract (GRE) and onion peel extract (OPE) as alternatives to antibiotics in reducing intestinal Salmonella spp. colonization and promoting healthy microbiota composition.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Obj. #1e To characterize GRE and OPE: Extract (OPE) successfully prepared from dried onion peels through various extraction methods.

Obj. #2 – To determine best inclusion levels to boost immunity in broiler chickens: The optimum dietary level of GRE (between 0.37% and 3%) that will comparatively enhance immune function in broiler chickens to a similar degree as the antibiotic, bacitracin methylene disalicylate (BMD), was determined during a 6-week experiment. Results showed that chicks that ate diets containing GRE at 0.75% or BMD (0.055 g/kg diet) had similar ($P > 0.05$) growth performance and immune function, and both treatments were superior ($P < 0.05$) to the other GRE treatments in this regard.

Obj. #3 - Evaluate efficacy of optimum dietary GRE & OPE levels in reducing intestinal Salmonella spp. in broilers: This objective was moved to Year #3 due to COVID19-related timeline constraints.

Obj. #4e Determine metabolomic signatures of GRE & OPE that protect against Salmonella spp: Blood plasma, breast tissue, cecal content, and feces were collected from chickens in Objective #2. Samples from chickens that ate diet containing 3% GRE (i.e. highest GRE level used in this study) were subjected to metabolomics procedures to determine whether ginger compounds (i.e. 6G, 8G, 10G, 6S, 8S, 10S) and their metabolites (i.e. Ginger-diols, M1, rp3, M9, M11) can be detected. Results showed that ginger compounds and metabolites were adequately detected, thereby creating the basis to analyze samples from the remaining treatments during Year #3.

Obj. #5 – Effect of dietary GRE & OPE on meat quality: Meat quality analysis was performed on breast meat samples collected from Objective #2. To date, results showed no difference ($P > 0.05$) among treatments in moisture, ash, and lipid content. Fatty acid methyl esters have been derived from lipid extracts obtained from each sample and are kept frozen at -80°C for future determination of fatty acid composition.

Briefly describe how your target audience benefited from your project's activities.

Results showed that GRE can be supplemented into broiler chicken diets to replace bacitracin methylene disalicylate antibiotic as a prophylactic during the first 3 weeks of life. Meat harvested from GRE-fed broiler chickens is expected to be microbiologically safer for human consumption and have health-promoting potential, thereby prompting a higher dollar value for the poultry industry.

Briefly describe how the broader public benefited from your project's activities.

a. During Year 2 (2020-2021) of this project, 4 undergraduates, 4 graduate students, 1 Postdoctoral researcher, and 1 research associate all belonging to underrepresented minority groups were trained on various experimental procedures and analyses.

b. One MS student, George Dosu successfully defended his thesis and graduated in summer 2021.

c. Graduate students received specialized training on how to execute live chicken trials and collect biological samples. This involved hands-on teaching of the following;
• How to prepare for the chicken trial
• How to properly and humanely handle the chicks
• How to execute a BSL2 chicken pathogen challenge trial
• keeping accurate records on the body weight and feed intake of chicks
• How to perform daily welfare check on the chicks
• Bleeding chicks to collect blood and harvesting plasma or (or serum) for downstream analysis.
• Necropsy of broiler chickens to collect various biological samples such as the spleen, small intestine, and ceca for downstream analyses.
• Training on Differential leukocyte counts and Enzyme-linked Immunosorbent assay.

d. Training on preparation of abstracts and presentation slides and posters.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Major changes or problems encountered in approach:

1. Research Associate (Dr. Obanla) resigned in December 2021 to take up better employment.
2. COVID19-Related Delays in Project Execution from March 2020 to December 2021:
a. During Year #1, we were forced to halt the preparation of dried onion peels, and delay starting work on Objectives #1 and #2 upon which remaining Objectives depended. Also, Ecclesias Extract Company had personnel shortages that resulted in longer time spent (>2 months) to optimize the onion peel extraction protocol.

b. We had to postpone Objective #2 chicken experiment from Year #1 to Year #2.
c. Provision of visas to international students was halted from 2020 to early 2021 and prevented timely recruitment of critical workforce for this project.
d. Dr. Sang is concerned that only 20% of Dr. Zhang (his Postdoc) and 0% of his salary is covered by this grant. This will reduce productivity during Year #3.
3. Dr. Da Silva experienced delay in executing meat quality analysis due to the renovation at Carver Hall (Summer 2021) and postponed meat sensory analysis till spring of 2022.
4. I estimate that the project is at least 1 year behind the original schedule.

Professional Development Opportunities Provided:
1. Dr. Fasina, Research Associate (Dr. Obanla), Postdoc (Dr. Khan) and 5 Graduate students all attended the virtual 110th Poultry Science Association Annual Meeting, Poultry Science Association, Virtual, USA. July 19-22, 2021.
2. Training by Nikon Representatives on how to use Computer-aided Camera and NIS-Elements Software to acquire Specimen Images from Microscope for Histomorphometric Analyses.
3. Training by ThermoFisher Representatives on how to use and maintain the CO2 incubator, microplate reader, and microplate washer.
Dissemination of results to communities of interest.

A. Refereed Journal Publications (*Denotes Student contribution)
1. Fasina, Y. O., T. O. Obanla, P. R. Ferket, and D. H. Shah. 2021. Comparative efficacy of Spray-dried plasma and Bacitracin methylene disalicylate antibiotic in reducing intestinal colonization by Salmonella spp. in broiler chickens. Poultry Science, 100: 101134 https://doi.org/10.1016/j.psj.2021.101134

2. Fasina, Y. O., T. O. Obanla, G. Dosu*, and S. Muzquiz*. 2021. Significance of Endogenous Antimicrobial Peptides on the Health of Food Animals. Frontiers in Veterinary Science, 8, 585266. https://doi.org/10.3389/fvets.2021.585266

B. Abstract Presentations at Professional Meetings (*Denotes Student contribution)
1. George Dosu* GS, Shengmin Sang, Temitayo Obanla, Tiffany Crenshaw*, Yewande Fasina. 2021. Dietary ginger root extract modulates fecal concentrations of Bifidobacteria and Lactobacillus in laying hens. Presented during the virtual 110th Poultry Science Association Annual Meeting, July 19-22.
2. George Dosu* GS, Shengmin Sang, Temitayo Obanla, Yewande Fasina. 2021. Effect of dietary ginger root extract on growth

performance and delayed-type hypersensitivity response of broiler chicks. Presented during the virtual 110th Poultry Science Association Annual Meeting, July 19-22.
3. Yewande Fasina, Nicholas Evans, Temitayo Obanla, Emily Kimminau, and Adam Fahrenholz. 2021. Mitigation efficiency of dietary medium chain fatty acid blend supplement on cecal colonization by Salmonella Enteritidis in broiler chicks. Presented at the 2021 Virtual International Poultry Scientific Forum, January 25-26.
4. Yewande Fasina. 2021. Essentials of Effective Remote Teaching. Presented at the Gamma Sigma Delta Virtual Seminar Series, March 17, 2021, NC A&T State University.
5. Joseph Richardson*. 2021. Effect of dietary spray-dried plasma on antibiotic susceptibility of Salmonella Enteritidis isolated from ceca of challenged broiler chickens. Presented at the Ag Research Seminar Series - Undergraduate Research Scholars' Spring 21 Presentations. North Carolina A&T State University. April 13, 2021. (Research Scholar: Joseph Richardson Mentor: Yewande Fasina, Ph.D.).

Continuation Plan for Remainder of Funding Cycle 2021-2022:
OBJECTIVE #1: Characterization of bioactive compounds and antioxidant potential of ginger root extract (GRE) and onion peel extract (OPE).
i. We will use chromatography and mass spectrophotometry techniques to characterize the bioactive compounds in the OPE extract that we obtained from dried onion peels. The OPE was prepared by Ecclesiastes Extract Company (Colorado Springs, CO).
ii. Determine the antioxidant potentials of GRE and OPE.

OBJECTIVE #2: Determination of the optimum inclusion level of ginger root extract and onion peel extract that will enhance immunocompetence in broiler chicks.
i. Complete analysis of liver and plasma samples collected for lipids.
ii. Determination of the expression levels of selected Antimicrobial Peptide genes.
iii. Histological evaluation of intestinal villi morphometry.
iv. Enumeration of indicator bacteria species in fecal samples.

OBJECTIVE #3: Evaluation of the efficacy of the optimum dietary inclusion level of GRE and OPE in reducing intestinal Salmonella spp. colonization in broiler chickens.
i. Execute Salmonella challenge trial to determine efficacy of GRE in reducing intestinal Salmonella spp. colonization.
ii. Execute Salmonella challenge trial to determine efficacy of OPE in reducing intestinal Salmonella spp. colonization.

OBJECTIVE #4: Metabolomic identification of bioactive compounds and metabolites that enhance resistance to intestinal Salmonella spp. colonization in broiler chickens.
i. Determination of GRE bioactive compounds and metabolites in feces, plasma, and breast meat to correlate highly sequestered bioactive compounds and metabolites in these samples to immune function data.

OBJECTIVE #5: Evaluation of the effect of GRE and OPE on meat quality in broiler chickens.
i. Gas chromatography analysis of fatty acid composition of breast meat from GRE chickens.
ii. Determination of lipid oxidation status of breast meat.
All Objectives: All students working on this project will be given opportunity to present at relevant conferences such as 2022 ARD Symposium (April, 2022) and Poultry Science Conference (in July, 2022).

Closing Out (end date 09/07/2023)

One- versus Two-layer of Plastic Covers for High Tunnel Tomato Production

Project Director
Mark Blevins
Organization
North Carolina Agricultural and Technical State University
Accession Number
1019917

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

It is not clear if high tunnels in North Carolina and regions with a similar climate should use one layer or two-layer plastic covers. To address this issue, this project looked at 1) the growth, yield and fruit quality of tomatoes grown in high tunnels with single- or double-layer plastic covers, and the microclimates under the two types of high tunnels; 2) the economic viability of using both types of high tunnels in tomato production for small scale, limited-resource and/or socially disadvantaged farms.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

In the 2020/21 fiscal year, the project has made significant progresses.

We transplanted Big Beef, Brandywine and Rebelski tomatoes in March in three one-layer and three two-layer plastic high tunnels (HT). We collected microclimate, plant growth and yield data. We collected early stage and late stage tomato samples from the two types of HTs and completed the analyses of pH, titratable acidity (TA), total soluble solid (TSS), lycopene and color. We also collected HT tomato yields, production input (materials and labor), as well as the daily market prices released by the North Carolina Department of Agriculture and Consumer Services, and have analyzed the data for enterprise budgets.

We found that the second layer of plastic enhanced plant growth but not the overall yield, compared to plants in one-layer plastic HT. Plastic mulch worked independently regardless of the layers of plastic on HT tomato yield but it reduced the redness of tomato fruits. For a same variety, tomatoes grown on plastic covered soil had higher TA, TSS, but lower lycopene content. Under the same planting and mulching conditions, Brandywine had significantly higher TA, TSS and lycopene contents than Rebelski. Two-layer HT benefited Rebelski and Brandywine grown in bare soil, but negatively affected Brandywine grown in plastic covered soil. Other than the additional costs of plastic film, inflator and electricity consumption, the operational expenses were similar between the one- or two-layer plastic covered HTs. Additionally, we conducted three workshops teaching farmers and agents about high tunnel vegetable production and its benefits.

All results from this year helped us achieve the goals and objectives of this project.

Briefly describe how your target audience benefited from your project's activities.

Our direct target audiences are small scale, limited-resource vegetable farmers, academic researchers, and students in agriculture/horticulture and food science.

Small farmers benefited from this project by participating in workshops showcased different types of high tunnels. They learned the increased yield and enhanced fruit quality of high tunnel tomatoes. They also benefited from learning the cost and return of high tunnel production in general and the pros and cons of having the second layer of plastic cover on the high tunnels.

Researchers and students benefited from the results provided at the regional and national meetings and conferences in the area of horticulture, family and consumer sciences, and agro-economics.

Briefly describe how the broader public benefited from your project's activities.

Tomatoes are nutritive and flavorful fruiting vegetable. They are rich in lipid soluble and water soluble antioxidants such as lycopene and vitamin C; they also contain significant amount of sugar and other organic acids that are important to the flavor. High tunnel is an inexpensive option to prolong growing and marketing seasons of fruits and vegetables with increased yield and enhanced fruit quality. The broad public benefits from the extended supplies of locally-produced and nutritious vegetables that ultimately promote public health.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

We encountered a few challenges in this fiscal year:

- We were not able to hire the research assistant until February 1, 2021.

- The pond provides water to the project on University Farm had a leak and needed to be totally drained, resulting a forced early project termination

- The walk-in freezer where fruit samples were stored had a fire that ruined all samples

- Co-PI Yu's lab was under renovation and research activities for sample analysis was stopped for August and September, which delayed the progress of sample analysis.

- We planned to quantify lycopene and vitamin C contents of tomato samples by HPLC, but our HPLC system was out of work due to aging and could not be repaired per the company. Thereby, we had to seek alternative methods to analyze samples.

We presented and published the results from this project and its predecessor.

- Gu, S. and Rana, T.S. (2021). Growth, yield and fruit quality of organic day-neutral strawberry in field and low tunnel settings in the southeastern United States. Acta Hortic. 1309, 447-456. https://doi.org/10.17660/ActaHortic.2021.1309.64.

- Gu, S. and Ballard, A. (2021). Low tunnels increased early-season yield of organic June-bearing strawberries in southeastern United States. Acta Hortic. 1309, 457-462. https://doi.org/10.17660/ActaHortic.2021.1309.65.

- Kafle, A., Gu, S., & Yang, G. (2020). Growth and Yield of Pak Choi in High Tunnels of Single- and Double-layers of Plastic Covers. HortScience 55(9) S427.

- Kafle, A., Gu, S., & Yang, G. (2020). A Comparative Study of Single versus Double Plastic Covers of High Tunnels on the Growth and Yield of Kale. HortScience 55(9) S383.

- Kafle A. Gu. S., and Yang G. 2021. Growth, Yield, and Fruit Quality of Cucumber in High Tunnels with Single- or Double-Layer Plastic Cover in North Carolina. HortScience 56(9) Supplement S8 (abstr).

- Kafle A. Gu. S., and Yang G. 2021. Effect of Single or Double Plastic Covers of High Tunnel on Growth, Yield, and Fruit Quality of Tomato. HortScience 56(9) Supplement S251-252 (abstr).

We also presented the general information of high tunnels and results from this project.

- Gu, S., & Fulk, R. (2021, Feb. 22). High Tunnel 101. AgriShop Academy-Western Region. (virtual).

- Gu, S., & Fulk, R. (2021, Feb. 26). High Tunnel 102. AgriShop Academy-Eastern Region. (virtual).

- Gu, S., Fulk, R., Kimes, J. E., & Moffitt, Q. (2021, Mar. 22-26). Winter Vegetable Production in High Tunnels of One- or Two-Layers of Plastic Covers. Small Farms Week. Greensboro, NC. (virtual).

- Gu, S. and Fulk, R. . High tunnel and over-winter vegetables. 2021 State Extension Conference. Oct. 25-27 (virtual)

For the next fiscal year (2021/22), we will remain focused on the proposed objectives.

- Continue the research and demonstration at A&T University Farm and the Small Farm Unit of the Center for Environmental Farming Systems.

- Upcoming outreach and Extension activities include presentations at:
  - The Small Farms Week in March 21-25.

  - Small Farms Field Day, June 16.

  - Fall Staff Institute agent training in mid-August.

- Upcoming conference presentations include:
  - Odediran, A., Mikiashvili, N., Yu, J., Coffey, P. L., & Gu, S. Quality Evaluation of Tomatoes Grown in Single-Layer and Double-Layer High Tunnels. 2022 NCAFCS Annual Conference, March 3-5, 2022. Kitty Hawk, NC.

Closing Out (end date 09/07/2023)

Improving Quality and Reducing Losses in Specialty Fruit Crops through Storage Technologies

Project Director
Penelope Perkins-Veazie
Organization
North Carolina State University
Accession Number
1020211

Quality of small fruits

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Most specialty fruit crops have a storage life of a few days to a few months. In this multi state project, collaborators work on technologies that will extend shelf life and maintain or improve quality. In this project, muscadines and blueberries were followed to determine quality changes during low temperature high humidity storage in ambient air conditions.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

We determined that seeded and seedless muscadine grapes had a storage life of 3 to 6 weeks, depending on genotype, when stored at 3 C and 90% relative humidity. Additionally, 60 blueberry cultivars were held at 3 C for 6 weeks and were found to differ most in maximum firmness and elasticity. These results help with extending shelf life and reducing food waste. Additionally, the composition of blueberry cell walls from firm and soft genotypes were followed to determine the polysaccharides most helpful in preventing softening and/or weight loss.

Briefly describe how your target audience benefited from your project's activities.

Growers benefit from knowing the amount of shelf life the traditional and seedless muscadines have when held at low temperature and can plan their distribution and marketing plans accordingly. Consumers benefit from having firmer blueberries available to them or with a longer shelf life to encourage purchase and consumption. Scientists benefit from knowing how cell walls in blueberry fruits vary among tissues and with genotypes and can begin to tailor strategies to breed for specific firmness attributes and discover genes important in berry hardness and elasticity that may respond to field temperatures during harvest (softening) or to rainfall (skin cracking).

Briefly describe how the broader public benefited from your project's activities.

The broader public ulitmately benefits through having more selection of fruits, having them available for longer periods of time, and by opening up demand that drives more production of these fruit.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Presentations have been made at 4 small fruit workshops geared for small and beginning growers, 4 presentations at local, regional and national meetings, and two invited talks at national meetings. One postdoc and two graduate students recieved training and professional development from these activities. Covid 19 delayed the progress of these projects as we were unable to get needed supplies to carry out some critical aspects. Publications from these studies are being prepared for submission to peer reivewed journals.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

Most specialty fruit crops have a storage life of a few days to a few months. As part of a multistate research project, NC State researchers are developing technologies that will extend shelf life and maintain or improve quality of muscadine grapes and blueberries. NC State researchers recently determined that seeded and seedless muscadines have a storage life of 3 to 6 weeks depending on their genetic characteristics when stored at 3 degrees Celsius and 90% relative humidity. In addition, 60 blueberry cultivars were held at 3 degrees Celsius for 6 weeks and were found to differ most in maximum firmness and elasticity. These results help growers plan their distribution and marketing to extend shelf life and reduce food waste. Scientists benefit from this insight as they tailor strategies to breed plants for optimal firmness and elasticity. The broader public ultimately benefits by having a broader selection of fruits, having them available for longer periods of time, and by opening up demand that drives more production of these fruits. This project exemplifies the kind of results that NC State research is delivering to feed our future and grow our economy.

Closing Out (end date 09/07/2023)

National Animal Genome Research Program

Project Director
Benjamin Reading
Organization
North Carolina State University
Accession Number
1018974

Seafood species genome resources, tools, and information

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

The goal of National Animal Genome Research Program NRSP-8 is to provide genome resources, tools, and information for all agriculturally relevant animal species in the United States. Our role in this national program is to coordinate efforts on all seafood species (fishes and shellfishes).

Objective 1: Advance the quality of reference genomes for all agri-animal species through providing high contiguity assemblies, deep functional annotations of these assemblies, and comparison across species to understand structure and function of animal genomes.

Objective 2: Advance genome-to-phenome prediction by implementing strategies to identify and validate genes and allelic variants predictive of biologically and economically important phenotypes and traits.

Objective 3: Advance analysis, curation, storage, application, and reuse of heterogeneous big data to facilitate genome-to-phenome research in agricultural animal species of agricultural interest.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Specific Major Activities Include:
Two (2) small research projects were funded in 2021 to provide preliminary data for grants (2022-2023). Leveraged funds from diverse grants based on previously funded small research projects totaled over $2,000,000 from federal sources in 2021. Collectively, this is almost $13 million reported since 2019 with a return on investment of 1:49 (NRSP-8, 2018-2023).

There were 32 publications from the NRSP-8 Aquaculture Community in 2021, including one US Department of Homeland Security report on Threats to Food and Agricultural Resources to the US Intelligence Community and 5 review papers or book chapters.

The Aquaculture Workshop in 2022 was canceled for in-person activities due to the COVID-19 pandemic and travel restrictions. A virtual workshop was hosted with the International Plant and Animal Genome (PAG) Conference via Zoom. Conference Attendees: 66 (an average of 35-45 Participants usually tuning into each presentation); Institutions Represented: 41; Countries Represented: 11

Travel Support & Opportunities for Trainings: In person travel to the 2022 PAG meeting and Aquaculture Workshop was canceled due to the COVID-19 pandemic. The travel of four students/postdocs was funded to cover the registration fee for PAG 2022. The purpose of the travel award program is to help graduate students and postdoctoral fellows to travel to the annual PAG meetings and present their research.

Machine Learning Workshop: A wide range of high-throughput technologies enable us to evaluate biological systems at various levels—at the genome, epigenome, transcriptome, proteome, and metabolome. These technologies are now being used to generate data to answer an ever-increasingly diverse set of questions. The next great challenge is integrating data analysis in a systems biology approach that utilizes novel supervised machine learning methods, which accommodate heterogeneity of data, are robust to biological variation, and provide mechanistic insight. The workshop will not focus on detailed mathematical models, but instead on how these machine learning tools may be used to analyze biological data, in particular gene and protein expression. The Workshop was led by Benjamin J. Reading (North Carolina State University).

Briefly describe how your target audience benefited from your project's activities.

The NRSP-8 Aquaculture Group is organized into species focus areas as follows and major accomplishments of each were:

Catfish

The complete germline repertoires of the channel catfish, *Ictalurus punctatus*, T cell receptor loci were obtained by analyzing genomic data from PacBio sequencing. Intraspecific genetic variability of the *Edwardsiella piscicida* pathogen recovered from diseased channel and hybrid (*I. punctatus* × blue *I. furcatus*) catfish were assessed and virulence associations among genetic variants was determined revealing 5 discrete phylogroups that correlated with virulence gene profiles. Rapid advances of second-generation sequencing (SGS) and third generation sequencing (TGS) is causing a paradigm shift from gene-based to genome-wide research in aquaculture. The major challenge for further implementation of genomic selection is associated with the costs and benefits of genotyping; Methods of low-cost genotyping hold potential and will help transfer the benefits to aquaculture industries. Global DNA methylation and gene expression profiles of feminized channel catfish during early sex differentiation after estrogen treatment show a specific set of genes that were differentially demethylated including sex differentiation-related pathways. Estrogen treatment of genetic males resulted in upregulation of female-related genes and downregulation of male-related genes during sex reversal. Sex reversal, however, did not cause changes in methylation or gene expression within the sex determination region (SDR) on chromosome 4, suggesting that estrogen induced sex reversal was a downstream process independent of the sex determination process regulated by sex-specific methylation within the SDR.

Oyster/Shellfish

Improved eastern oyster (Crassostrea virginica) reference genome assembly using updated assembly pipeline, additional Hi-C data, and high-density genetic linkage map. A high-quality reference genome for the eastern oyster (*Crassostrea virginica*) and whole-genome sequence data of samples from across the species range in the USA was used to explore structural variation across the genome of this species. Re-sequencing of an additional 179 wild and selected individuals from 16 eastern oyster populations situated along the US east Coast >20X coverage. A seascape genomics approach was used to investigate population structure, local adaptation, and the extent to which environmental gradients influence genetic variation among natural and restored populations of Chesapeake Bay eastern oysters. Response of selectively bred Eastern oysters exposed to

Perkinsus marinus (Dermo disease) was evaluated. Completion of Affymetrix 60K SNP chip for U.S. East Coast eastern oyster populations; the SNP array is available through Thermo Fisher. Differences in DNA methylation patterns for 50 families of Pacific oyster (*Crassostrea gigas*) were characterized based on heat-resistant phenotypes. Complementary methods of metagenomics and metaproteomics were applied to more fully characterize bacterial taxa in shellfish hatchery water at high and low pH. The complementary methods of metagenomics and metaproteomics contribute to a more complete characterization of bacterial taxa that are potentially active versus truly metabolically active and thus impact water quality and inter-trophic relationships. Eastern Oyster Genome Workshop, held during the *National Shellfisheries Association Annual Meeting* (virtual) and Genomic selection was initiated in an eastern oyster breeding program (VIMS).

Trout and Salmon

The first *De-novo* genome assembly for the North American Atlantic salmon lineage was submitted to NCBI and is in final review. A new transcriptome assembly using PacBio long-read sequencing improved the rainbow trout genome annotation and identified alternative splicing associated with economically important phenotypes in rainbow trout. Genomic selection models trained on 2,000 animals increased predictive accuracy compared to the traditional pedigree-based model by up to 50% for Fillet Yield and 28% for Body Weight, which suggests that using genomic selection can substantially enhance genetic improvement for traits in aquaculture. An improved genomic prediction for fillet yield and firmness in rainbow trout was achieved using reduced-density SNP panels. The genetic architecture of resistance to infectious hematopoietic necrosis virus (IHNV) was found to be oligogenic with a few moderate effects QTL and many loci with small effects in two commercial aquaculture breeding populations. A study revealed that sRNAs enriched in outer membrane vesicles of pathogenic *Flavobacterium psychrophilum* interact with immune genes of rainbow trout. Markers associated with adult migration were validated for natural and hatchery origin populations of Chinook salmon and steelhead, with genotypes explaining between 50-80% of phenotypic variation. Markers associated with age-at-maturity in steelhead were validated for natural and hatchery origin populations, with genotypes explaining 10-17% of phenotypic variation depending on sex. Whole genome resequencing in coho salmon identified a sex determining region that was validated with amplicon assays, along with candidates for differing phenotypes of adult migration. Whole genome resequencing in ecotypes of redband trout identified a candidate gene (ceramide kinase; *cerk*) associated with thermal adaptation phenotypes. Whole genome re-sequening and landscape genomics analyses of Chinook salmon populations revealed candidate regions of the genome associated with environmental factors responsible for local adaptation.

Striped Bass

The second version (2.0) of the striped bass genome draft was fully annotated through the NCBI Eukaryotic Genome Annotation Pipeline and is publicly available (GenBank accession GCA_004916995.1). The Dovetail Genomics Hi-Rise pipeline was employed to create a white bass genome assembly that was uploaded to NCBI (DOM_MoChry_2.0, GenBank Accession no. GCA_019097615.1); This genome has not yet been fully annotated, but it is publicly available. A machine learning pipeline was developed to analyze 15,000 single nucleotide (SNP) markers (expressed quantitative trait loci, eQTL) that were identified among muscle transcriptome data generated from hybrid striped bass. A deeper pathway analysis is currently being conducted to examine the relationship of these gene expressions in white muscle tissue for predictive phenomics of growth performance. Synthetic piscidin antimicrobial peptides were produced and demonstrated to have broad antimicrobial activity and potent inhibition of bacterial biofilm growth as a novel alternative to antibiotics. Genetically improved F6 striped bass and F10 white bass broodstock were transferred to industry from the *National Breeding Program for the Hybrid Striped Bass Industry;* F7 generation captive bred striped bass seed with 25% better growth were also disseminated to commercial aquaculture producers. Twelve (12) graduate students and post docs were trained in machine learning approaches in biological sciences including application of pattern recognition to evaluate gene and protein expression related to predicting phenotypes in a variety of agriculturally important animals, including fishes and well as poultry; a CRISPR/Cas9 Guide to RNA design was published for student training.

Briefly describe how the broader public benefited from your project's activities.

Extramural funding agencies leveraged through collaborations and seed funding opportunities provided by this NRSP-8 program include NOAA, USDA NIFA, USDA AFRI, NSF, and the FFAR. In particular, the marine finfish and shellfish aquaculture initiatives of USDA and NOAA
are to be recognized (Executive Order 13921: Promoting American Seafood Competitiveness and Economic Growth). Generally, genomic information of most aquatic species is still lacking and greatly lagging behind that of terrestrial species.

Homeland Security Presidential Directive 9 (HSPD-9) directs the US Department of Homeland Security to coordinate the overall national effort to protect the Food and Agriculture Sector. From the Threats to Food and Agricultural Resources report (2021) and relevant to USDA NRSP-8: “Innovation is a crucial aspect of the Food and Agricultural Sector. The U.S. public-private R&D sector is developing plant varieties and new terrestrial and aquatic animal breeds, biomanufacturing processes, and omics profiles…that provide competitive commercial advantages with national security relevance. However, R&D within U.S. organizations are the target of foreign cyber espionage, trade secret, and intellectual property theft. Food and Agriculture key R&D players, including large corporations, are not the only victims. The most vulnerable are small and emerging corporations, universities, and government research organizations…Cyber intrusions can be used to replicate the owner’s products and compete in global markets in high-value food sectors. Cybertheft of data and algorithms can provide competitive advantages and coercion points on aggressive corporate takeovers of U.S. corporations…As genomic data become linkable to other data sources, individuals, animal, or plant breeds become identifiable and potentially a target of malicious activities….Much of this [genomic] data and the algorithms to mine this information reside in private repositories that state and non-state actors can target to steal, destroy, modify, and therefore disrupt years of costly research. At the same time, these attacks can modify genomic information to decrease the bioforensic and attribution capabilities of the U.S…”

The NRSP-8 has a very important mission in this regard as purveyors and stewards of these critical data.

Members of the NRSP-8 Aquaculture Group contributed content matter expertise to advise US Department of Homeland Security and the Office of the Director of National Intelligence on national food security issues, particularly related to seafood. Contributions were published in the following 2021 report:

Threats to Food and Agricultural Resources. United States Department of Homeland Security, Office of Intelligence and Analysis, Analytic Exchange Program. 95 pp.

https://www.dhs.gov/sites/default/files/publications/threats_to_food_and_agriculture_resources.pdf

Additional information is provided in US DHS AEP Report Threats to Food and Agricultural Resources (2021).

6. The U.S. government needs to promote domestic aquaculture for food production. Since 90% or more of the seafood consumed in the U.S. is imported, the country is mostly reliant on foreign sources to provide this food commodity. This dependency creates an economic and food supply vulnerability. A future focus of the Food and Agriculture Sector should be to promote domestic U.S. aquaculture production to meet this seafood demand and efforts should extend beyond regulations of seafood imports. This will be critical for meeting future food-animal protein demand of the American publics.”

“In May of 2020, Executive Order 13921 Promoting American Seafood Competitiveness and Economic Growth was released that detailed improving American competitiveness in the global seafood market to help detract from this massive economic impact of the trade deficit and to re-direct priorities toward securing the domestic U.S. seafood supply.49 These priorities also align with Executive Order 14017 to secure America's Supply Chains (February 2021) and Executive Order 14036 on Promoting Competition in the American Economy (July 2021).”

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

The National Animal Genome Research Program provides resources, tools, and information for all agriculturally relevant animal species in the US. NC State supports this program by coordinating efforts on all seafood species. As part of this effort, NC State researchers have developed genetic selection models that improve the ability to predict animal filet yield by 50% and the ability to predict animal body weight by 28%, suggesting that using these models can substantially enhance genetic improvement of aquaculture animals. NC State research has also uncovered insights into disease resistance and environmental adaptation in commercially important fish species. In addition, genetically improved striped bass and white bass broodstock were transferred to industry, and captive bred striped bass seed with 25% better growth were delivered to commercial aquaculture producers. By delivering these insights, NC State is enhancing the value and resilience of domestic aquaculture to grow the economy of NC and the US as a whole.

Closing Out (end date 09/07/2023)

Understanding how symbiotic fungi affect plant productivity and stress resilience across scales

Project Director

Christine Hawkes

Organization

North Carolina State University
Accession Number
1018688

Expanding our toolkit for agricultural management by understanding the microbiome

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

The plant microbiome can partly control how well plants can resist drought and pathogens and access soil nutrients. As these stressors continue to significantly reduce crop yields and the cost of fertilizers increases, the microbiome can expand our toolkit for agricultural management. To do so, however, requires a better understanding of how the microbiome assembles on the plant, the mechanisms by which the host phenotype is affected, and how these effects scale across space and species. To that end, we study the fungi living inside plants, which we have demonstrated have large impacts on host physiology, stress tolerance, and survival. We work across both natural and agricultural ecosystems to understand both the basic and applied ecology, genetics, and metabolomics of these fungal-plant interactions.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Approaches

We use a combination of greenhouse and field studies to address questions about plant-fungal communities and their function. In the greenhouse, experiments in which a single plant host is inoculated with a single fungal strain allow us to isolate fungal effects on the plant and to identify mechanisms underlying those effects. By increasing the number of fungi inoculated, we can also examine how higher-order interactions among fungi change both the effect on the host plant and the mechanism of action. We have greenhouse studies to address how (1) plant metabolites and gene expression mediated by foliar fungi affect switchgrass stress physiology, (2) foliar endophytes affect plant resistance to pathogens, (3) root endophytic fungi in switchgrass contribute to host nutrition via organic and inorganic sources of nitrogen and phosphorus, and (4) individual fungal effects scale up to communities of 2-8 taxa.

Field studies in natural and agricultural ecosystems are used to examine how fungal communities assemble in real-world conditions. In addition, we use field inoculations of fungi on plants to determine how fungal effects observed in controlled conditions are altered in a more complex environment where other microbes, plants, insects, and weather can modify outcomes. We have used field approaches to (1) examine source-sink dynamics of foliar fungi in the native Hall's panic grass (Panicum hallii), (2) identify landscape-level drivers of switchgrass (Panicum virgatum) leaf, root, and soil microbiomes, (3) test real-world function of foliar endophytes of switchgrass identified as beneficial in controlled greenhouse conditions, and (4) compare local-to-landscape drivers of foliar fungi in corn, soy, wheat, and switchgrass.

In both greenhouse and field experiments, we use a wide variety of measurements including ecological, physiological, chemical (metabolomics), and gene-based (metagenomics and transcriptomics).

Collaborators

These efforts are highly collaborative. At NCSU, we work with faculty across 3 colleges to address different aspects of the problems including quantitative crop genetics and pathology (Dr. Peter Balint-Kurti, USDA-ARS and Entomology and Plant Pathology, (Dr. Cristina Cowger USDA-ARS and Entomology and Plant Pathology , and Dr. Gina Brown-Guedira, USDA-ARS and Crop and Soil Sciences,), CRISPR/Cas editing of filamentous fungi (Dr. Kevin Garcia, Crop and Soil Science and Dr. Nathan Crook, Chemical and Biomolecular Engineering), modeling of gene networks (Dr. Ross Sozzani, Plant and Microbial Biology and Dr. Cranos Williams, Electrical and Computer Engineering), and imaging technologies (Dr. Mike Kudenov, Electrical and Computer Engineering and Dr. Joshua Gray, Forestry and Environmental Resources). Finally, we work with Ryan Heiniger (Crop and Soil Sciences) on field experiments and extension; he has given multiple field day presentations on plant microbiomes and developed an extension handout and video on the topic.

Outside of NCSU, we collaborate on the role of root endophytes and plant nutrition with Dr. Jennifer Pett-Ridge (Lawrence Livermore National Lab), on metabolomics mechanisms with Dr. Moriah Sandy (University of California San Francisco), and on the role of the wheat microbiome in crop resilience with Dr. Lars Hansen, Dr. Rasmus Kjoller, Dr. Jan Christensen, and Dr. Svend Christensen (all University of Copenhagen).

Briefly describe how your target audience benefited from your project's activities.

Chemical mechanisms

To address the role of fungal-mediated metabolites in extending host phenotypes, we measured switchgrass (*Panicum virgatum*) traits when inoculated with 16 foliar fungal endophytes. Overall, we found that fungi resulting in terpenoid-rich leaf tissues were associated with larger, more physiologically active plants and fungi generating phenolic-rich leaves were associated with smaller, less active plants. **Only 47 metabolites were enriched in plants colonized by fungal endophytes relative to fungus-free controls, and of these, 12 metabolites explained from 14-43% of plant trait variation.** Fungal long chain fatty acids and sterol precursors were positively associated with plant photosynthesis, conductance, and shoot biomass, but negatively associated with survival. The phytohormone gibberellin, in contrast, was negatively associated with plant physiology and biomass. **These results inform our ongoing efforts to develop metabolites as crop management tools.** A manuscript reporting on these results is currently under review.

Genetic mechanisms

To address how fungal-mediated plant gene expression relates to host drought physiology, we focused on *Panicum hallii* responses to fungi that generate “water saver” and “water spender” physiological strategies in the host. Water-savers minimized water loss, enhanced wilt resistance, and increased survival, whereas and water-spenders maximized water uptake, decreased wilt resistance, and reduced survival. There was surprisingly little overlap in differentially expressed genes or gene regulatory pathways across the fungi. **This suggests that endophytic fungi can employ highly diverse means to alter host plant phenotypes.** Nevertheless, using lasso regression **we identified a small subset of genes that predicted up to 81% of the variation in plant water loss and wilt resistance under drought. Most of these genes were not previously known to be altered by fungal colonization, despite documented roles in abiotic stress responses.** For example, expression of C3HC4 zinc finger proteins is known to increase with heat, drought, and salinity stress, and their overexpression can improve stress tolerance. Here, increasing differential expression of two C3HC4 zinc finger proteins resulted in more water loss and reduced wilt resistance, respectively, which was lessened by the water-saver fungi. **Clearly, fungi can differentially moderate specific plant genes to improve or worsen drought tolerance in the plant host and their effects on plant gene expression may indicate how they extend the plant phenotype. The comparison across multiple fungi allows us to differentiate broadly fungal-responsive genes vs. those that are unique to single fungal taxa. The genes identified here are putative targets for future study to understand their function and, ultimately, represent candidates for precision breeding efforts to increase plant drought tolerance.** A manuscript based on these results is currently under review.

Nutritional mechanisms

We tested the functional role of 44 root endophytes to transfer either inorganic or organic sources of nitrogen and phosphorus to switchgrass. The fungi had a wide range of effects on the plant, for example, altering plant biomass by 0.6-1.6x for inoculated compared to fungus-free plants and by 0.14-1.7x for fungi in inorganic vs. organic nutrient treatments. To understand the role of root endophytes in plant nutrition, approximately 600 tissue samples were submitted for nutrient analysis. We will use the results to select a subset of fungi with differential nutrient access for more mechanistic studies. **This work has the potential to provide us with another pathway to improving plant nutrition in agriculture that does not rely on the development of undisturbed networks of mycorrhizas, which is particularly important given the rising cost of fertilizer.**

Fungal community assembly in a native grass

We examined source-sink dynamics of foliar fungi in the C4 grass, *Panicum hallii*, at ten grassland sites across a rainfall gradient at local, regional, and gradient-wide scales. Overall, we found that source-sink dynamics were local, with high dispersal limitation and strong environmental filtering. Plants were significantly more important sources than soils, but contributions from neighboring C4 grasses and dicots were surprisingly similar. Only 4% of fungal taxa were unique to *P. hallii*,

suggesting that **identification of core microbiomes in single host plant species may be misleading. This work contrasts with previous results for plant-associated bacteria, emphasizing the importance of local plant-to-plant fungal transmission rather than soil-to-plant.** Results were published in 2021 (10.1007/s00248-021-01836-2).

Crop fungal community assembly across scales

We compared foliar fungal microbiomes of maize, soy, wheat and switchgrass from four common garden sites across North Carolina. We found that **the best predictors of crop fungi were plant traits such as height and leaf area, as well as recent low temperatures, which acted as robust local filters on assembly**. However, **regardless of crop, the surrounding landscape appears to provide the source of local fungi** – richness and plant-to-plant heterogeneity went up with increasing natural vegetation cover, whereas fungi become less diverse and more homogeneous with additional crop cover in the 1-10km region surrounding the target fields. **These results are consistent with previous work showing that adjacent natural vegetation provides crop fields other beneficial ecosystem services** (e.g., pollination, runoff buffering, insect predation), and supports the need for agricultural management in a broader landscape context.

Scaling up to fungal communities

We asked how individual foliar fungal effects on plant traits scale to communities of 2, 4, and 8 fungal strains. **We found dramatic variation in leaf physiology of plants colonized by 2 fungi was suppressed by additional fungal diversity, and that higher levels of diversity were also associated with more signs of fungal pathogenic behavior in the plants**. We have since prepared mock communities (both even and uneven) for each diversity treatment using qPCR, which will allow us to quantitatively assess actual foliar fungal assembly in each condition. These samples will be submitted to the core facility for sequencing in spring 2022. Ultimately, the **results will speak to how higher-level interactions will affect community assembly and function, which is also important for the development of effective inoculants**.

Fungal effects on pathogen resistance across hosts

Using isolates from corn, wheat, and switchgrass, we tested how endophytes isolated from the annual crops vs. switchgrass inhibited crop-specific pathogens (southern leaf blight in corn and Septoria nodorum blotch of wheat). **Both pathogens were inhibited by twice as many fungal isolates from switchgrass compared to those isolated from annual crop hosts, suggesting that less disturbed perennial stands may harbor more beneficial taxa**. We selected a subset of 21 phylogenetically diverse fungi that represent a range of in vitro inhibition of pathogens to test against southern leaf blight in gnotobiotic maize plants grown in microcosms. Later in spring, we will run field tests where rows of endophyte-colonized maize plants are placed between rows of maize inoculated with southern leaf blight. Wheat will be tested similarly in the fall.

Briefly describe how the broader public benefited from your project's activities.

Plant microbiomes represent potential tools to improve agricultural production while also enhancing sustainability. However, in order to leverage microbiomes in real-world ecosystems, we must discern both the ecological drivers of plant-microbiome associations, their benefits, and underlying mechanisms that generate host effects. To date, we have identified the environmental controllers of microbiome community assembly across local to regional scales, demonstrated that plant-associated fungi mediate the plant stress phenotype, and have begun the identifying the genes and metabolites that underpin fungal effects on the host. Each of these efforts represents a step forward in translating the plant microbiome for effective applications.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Training

Six undergraduate students received training as part of this work, including four women and one student from an underrepresented group. Each student was trained in methods ranging from fungal culturing to DNA extractions. In addition, one student, Maggie Wilson, carried out an independent project assessing how root endophytes alter root structure in switchgrass using image analysis.

Postdoc Catherine Aimone and graduate students Rachel Hammer and Xavious Allen were trained on how to use the NCSU Henry2 High Performance Computing Cluster. Catherine Aimone also took a five-part training and certification in Linux command line, and expanded her experience significantly by serving as a Software Liason for the NCSU Bioinformatics User Group where she coordinated and established a systematic environment for script sharing among Henry2 users in GitHub and Gdrive. For professional development, she took 60 hours of project management training through the Project Management Podcast. Xavious Allen was further trained in culturing approaches and RNAseq analysis of plant material. Rachel Hammer took a data visualization workshop and was trained in methods to measure microbial function through respiration and enzymes. Research Associate Elizabeth Thomas received training in Illumina library preparation for amplicon metagenomics.

Related publications

Whitaker B, Giauque H, Timmerman C, Birk N, **Hawkes** CV (2021) Local plants, not soils, are the primary source of foliar fungal community assembly in a C4 grass. Microbial Ecology doi: doi: 10.1007/s00248-021-01836-2

Zhalnina K, **Hawkes** CV, Shade A, Firestone M, Pett-Ridge J (2021) Managing plant microbiomes for sustainable biofuel production. Phytobiomes J 5: 3-13. doi: 10.1094/PBIOMES-12-20-0090-E

Hawkes CV, Kjøller R, Raaijmakers JM, Riber L, Christensen S, Rasmussen S, Christensen JH, Dahl AB, Westergaard JC, Nielsen M, Brown-Guedira G, Hansen LH (2021) Extension of plant phenotypes by the foliar microbiome. Annual Review Plant Biology 72: 823-46 doi: 10.1146/annurev-arplant-080620-114342

Lee M, **Hawkes** CV (2021) Co-occurrence of Glomerales and Sebacinales in switchgrass roots and soils. Plants, People, Planet 3: 614-626 doi: 10.1002/ppp3.10181

Kivlin SN, **Hawkes** CV, Papes M, Treseder KK, Averill C (2021) The future of microbial ecological niche theory and modeling. New Phytologist 231: 508-511. doi: 10.1111/nph.17373

Presentations

In 2021, postdoc Catherine Aimone gave a talk on the project to the Microbiome Seminar Series at NCSU entitled, “Using host transcriptomes to elucidate the mechanism of endophyte-mediated drought tolerance.” Via zoom, Hawkes also gave (1) a seminar at University of Illinois Urbana-Champaign Institute for Genomic Biology on “Microbial responses to environmental change” and (2) a talk at an AGU Town Hall on “Resilience, resistance, and recovery of microbial function and community composition.”

Other products

We developed and optimized methods for gnotobiotic methods in maize and wheat, including sterile seed germination and microcosm design. We also increased our culture library based on sampling additional wheat plants across North Carolina.

Plans for 2022-23

We will carry out several new experiments in the coming year: (1) test local sources of wheat foliar microbiomes in herbaceous and woody vegetation adjacent to 7 common gardens across North Carolina, (2) examine higher order interactions of root fungal communities on switchgrass nutrition using greenhouse experiments, and (3) test crop and switchgrass isolates on pathogen resistance in maize and wheat in microcosms and field experiments. We will also (4) complete RNA-seq and amplicon metagenomics analysis of wheat leaves collected from Septoria nodorum blotch nurseries collected in 2021. Finally,

we plan to analyze data and submit publications from completed experiments including: (5) the fungal diversity experiment, (6) the root fungal assays once nutrient data are available, and (7) bacterial data from switchgrass leaves, roots, and soil across 14 sites in North Carolina in 2018. This plan assumes no additional effects of the COVID-19 pandemic.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

The plant microbiome can partly control how well plants can resist drought and pathogens and access soil nutrients. As these stressors continue to significantly reduce crop yields and the cost of fertilizers increases, the microbiome can expand our toolkit for agricultural management. Using a combination of greenhouse and field studies, questions about plant-fungal communities and their function were examined through collaborative efforts involving researchers in multiple states.

Researchers found that fungi resulting in terpenoid-rich leaf tissues were associated with larger, more physiologically active plants and fungi generating phenolic-rich leaves were associated with smaller, less active plants. Fungal long chain fatty acids and sterol precursors were positively associated with plant photosynthesis, conductance, and shoot biomass, but negatively associated with survival. These results inform our ongoing efforts to develop metabolites as crop management tools. A manuscript reporting on these results is currently under review. To address how fungal-mediated plant gene expression relates to host drought physiology, researchers identified a small subset of genes that predicted up to 81% of the variation in plant water loss and wilt resistance under drought. Most of these genes were not previously known to be altered by fungal colonization, despite documented roles in abiotic stress responses. The genes identified here are putative targets for future study to understand their function and, ultimately, represent candidates for precision breeding efforts to increase plant drought tolerance. A manuscript based on these results is currently under review.

To date, we have identified the environmental controllers of microbiome community assembly across local to regional scales, demonstrated that plant-associated fungi mediate the plant stress phenotype, and have begun the identifying the genes and metabolites that underpin fungal effects on the host. Each of these efforts represents a step forward in translating the plant microbiome for effective applications.

Closing Out (end date 09/07/2023)

Economic Evaluation of Crop Insurance, Risk, and Technology Issues in Agriculture

Project Director
Roderick Rejesus
Organization
North Carolina State University
Accession Number
1016753

Economic evaluation of crop insurance, risk, and technology issues in agriculture

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

To further understand the economic and risk impacts of crop insurance and agricultural technology issues has the potential to benefit the U.S. agricultural industry, in general, and North Carolina agriculture, in particular. Specific objectives are: (1) To analyze actuarial and economic issues related to various crop insurance program rules, components, and rating procedures, and (2)To assess the economic and risk impacts of new and emerging agricultural technologies in the US and developing countries.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

The main activities is to conduct research and publish results in peer-reviewed outlets. We have made significant progress in achieving the goals of the project by publishing the following papers from 10/1/2020 to 9/30/2021:

Li, Z., **R.M. Rejesus**, X. Zheng. “Nonparametric Estimation and Inference of Production Risk.” *American Journal of Agricultural Economics*. Vol 103, No. 5 (October 2021): 1857-1877.

Martins, L.B., **R.M. Rejesus**, C. Reberg-Horton, R. Myers. “Understanding the market for cover crop seeds in the United States: Background and potential policy directions.” *Journal of Soil and Water Conservation*. Vol. 76, no. 5 (September/October 2021): 83A-88A.

Wang, R., **R.M. Rejesus**, J.B. Tack, S. Aglasan. “Do Higher Temperatures Influence How Yields Respond to Increasing Planting Density?” *Agricultural and Resource Economics Review*. Vol. 50, No. 2 (August 2021): 273-295.

Rejesus, R.M., S. Aglasan, L.G. Knight, M.A. Cavigelli, C.J. Dell, E.D. Lane, D.Y. Hollinger. “Economic Dimensions of Soil Health Practices that Sequester Carbon: Promising Research Directions.” *J. of Soil and Water Conservation*. Vol. 76, No. 3 (May/June 2021): 55A-60A.

Brown, Z.S., L. Connor, **R.M. Rejesus**, and J.M. Yorobe, Jr. “Landscape-level feedbacks from large-scale adoption of transgenic pesticidal maize in the Philippines.” *Ecological Economics*. Vol. 180 (February 2021): Article 106883: 1-11.

R.M. Rejesus and M.S. Jones. “Perspective: enhancing economic evaluations and impacts of integrated pest management farmer field schools (IPM-FFS) in low-income countries.” *Pest Management Science*. Vol 76, No. 11 (November 2020): 3527-3536.

Briefly describe how your target audience benefited from your project's activities.

The targe audience of agricultural economists, academics, government agency personnel, agricultural scientists, farmers, and policy-makers (in the
executive and legislative branch). benefited through the important knowledge generated by the peer-reviewed publications.

Briefly describe how the broader public benefited from your project's activities.

The broader public benefited from the project activities through the production of science-based evidence that can e used by poliy makers in making decisions.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

To further understand the economic and risk impacts of crop insurance and agricultural technology issues, NC State researchers have conducted research and published 6 articles in the following peer-reviewed journals: the American Journal of Agricultural Economics, the Journal of Soil and Water Conservation, Agricultural and Resource Economics Review, Ecological Economics, and Pest Management Science. These articles provide key information to diverse agricultural stakeholders, including insights into production risk prediction, market and policy shifts, the influence of higher temperatures on plant yields, and the impacts of new and emerging agricultural technologies in the US and in developing nations. Information derived from these research articles provide important implications to policy makers and stakeholders. By providing these insights, our world-leading faculty remain at the forefront of the interdisciplinary innovation that is critical to creating economic, societal, and intellectual prosperity.

Closing Out (end date 09/07/2023)

Identifying factors that reduce the reproductive quality of honey bee queens (Apis mellifera L.)

Project Director
David Tarpy
Organization
North Carolina State University
Accession Number
1016832

Results for Project Period 10/1/2020 - 9/30/2021

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Objective 1: Measure sperm viability over time within queens' spermathecae to determine patterns in sperm- and queen longevity; Objective 2: Experimentally manipulate queens' hive environments, calculate requeening success, and measure the reproductive quality of replacement queens; Objective 3: Determine the minimum mating number by queens that confer colony-level benefits of increased intracolony genetic diversity; Objective 4: Quantify the population structure and genetic diversity of the U.S. breeding population of honey bees.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

We have investigated the sperm viability of queens over time, manipulated queen reproductive quality to determine their effects of phenotype, and calculated the benefits of multiple mating by queens on colony health.

Briefly describe how your target audience benefited from your project's activities.

Nothing to report

Briefly describe how the broader public benefited from your project's activities.

In 2021, the PI has had 19 presentations or workshops to beekeeper groups accounting for ~2,669 individual contacts. He has also published 15 extension publications, as well as covered in one media report.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

Honey bees play a crucial role in pollinating diverse crops. NC State researchers are conducting research to determine the environmental and management factors that influence the longevity and fertility of honey bee queens, since queen problems are one of the major triggers of honey bee colony losses. In 2021, these insights were delivered to beekeeper groups and other stakeholders via 19 presentations and workshops (>2,500 individual contacts) and 15 Extension publications. Moreover, the NC State Queen & Disease Clinic is a unique Extension initiative that enables queen producers and beekeepers to test the health and quality of their queens and colonies in near-real time so that they can optimize their management practices to improve honey bee health and survival. These are just some of many ways that NC State's world-leading faculty are at the forefront of apicultural innovation and discovery.

Closing Out (end date 09/07/2023)

Impact of Moringa Oleifera Supplementation on Sow and Piglet Performance

Project Director
Radiah Minor
Organization
North Carolina Agricultural and Technical State University
Accession Number
1016690

Impact of Moringa Oleifera Supplementation on Sow and Piglet Performance

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Milk is critically important for supporting neonatal growth, development, and health during both the pre- and post-weaning periods and a mother's nutrition during gestation and lactation periods significantly impact the quantity and quality of milk and thus the vitality and vigor of neonates. *Moringa oleifera Lam* is a tree packed with many vitamins, minerals, phytochemicals, and antioxidant compounds that promote health in humans and several livestock species (chickens, pigs, cows, and goats). Also known as "Mother's best friend", Moringa has been shown to increase milk production; however, information relating to whether or how it influences milk production of pigs is lacking. Furthermore, what impact feeding Moringa to sows during gestation and lactation has on milk and the health and growth of piglets are not fully characterized. This project investigates whether Moringa can be used as a nutritional supplementation to improve milk quality and quantity and the health and growth of piglets (birth to weaning).

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

The goal of this project is to determine the benefit of Moringa on reproductive performance, milk composition and performance of young. During this reporting year (2020-2021), we were able to complete some baseline experiments to better understand and characterize the protein content of milk from swine not given Moringa as a supplement. Using a high-throughput experimental protocol we reported that levels of nutritional and bioactive proteins present in swine milk change throughout lactation as milk matures. As a follow up to this work, we investigated how levels of swine milk-associated cytokines change overtime. Cytokines are proteins associated with immunity, growth differentiation, and development and in milk have been shown to be involved in mammary cell function as well as impact the sucking neonate. Finally, we worked to develop and optimize several experimental protocols and in vivo model systems critical to the lab achieving research goals related to this project. First, we developed a protocol for, and trained a student in the method of collecting milk from mice. This was done to allow us to evaluate the impact that Moringa makes on milk production quantity and quality (changes in milk components) in mice. Secondly, we began developing an in vitro model system to investigate the impact that Moringa makes on the inflammatory responses of pig white blood cells.

Briefly describe how your target audience benefited from your project's activities.

From this work, we will have a better understanding of swine milk with regards to protein levels and how certain proteins change during the lactation period. Furthermore, we have contributed to the effort to characterize swine milk content as it relates to cytokine content. This information is useful for management of sucking young during lactation. Knowing when certain nutrients, proteins and bioactive factors are present will help producers assure that piglets are getting the most nutrients to support growth, health, and immunity. Moreover, identifying a supplement such as Moringa that can boost the quantity and/ or nutritional value of the milk would be of great value to the swine industry.

Briefly describe how the broader public benefited from your project's activities.

These findings could be relevant to agriculture as it could have implications for all milk producing livestock animals and humans. Our research will also add to the knowledge on how Moringa supplementation benefits livestock production systems and therefore would also increase the demand for this plant and therefore would serve as an additional crop for growers.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

We experienced a few challenges that impacted scope and project timeline. This included facility issues, equipment issues and personnel/student issues.

1) This year the lab moved into a new space. The completion of the move was delayed because of laboratory safety and compliance protocols. 2) We also experienced a malfunction with tissue culture incubators.

2) The social distancing requirements stemming from the pandemic put a strain on the ability to work in the lab and properly train students in the techniques needed to complete projects independently.

3) Our long-time technician left the lab for another position this left a significant deficit as she was critical for training and supervising student as well as optimizing protocols and completing experiments.

The results of the experiments have been disseminated in the following peer-reviewed publications:

1) Bradshaw, C., Suarez-Trujillo, A., Luecke, L., Aryal, U., Stewart, KR., Ramirez Ferreira, C., Casey, TM & Minor, RC. (2021) Shotgun proteome analysis of homogenate milk samples reveals dynamic changes in milk proteins across sow lactation and relative abundance of proteins to each other. Journal of animal science, 99(9), skab240. https://doi.org/10.1093/jas/skab240.

2) Suarez-Trujillo, A., Luecke, S. M., Logan, L., Bradshaw, C., Stewart, K. R., Minor, R. C., & Casey, T. M. (2021). Changes in sow milk lipidome across lactation occur in fatty acyl residues of triacylglycerol and phosphatidylglycerol lipids, but not in plasma membrane phospholipids. *Animal*, *15*(8), 100280.

A student also presented a poster:

Pittman,T., Bradshaw, C., Suarez-Trujillo,A., Casey,TM, and Minor, RC. (September, 2021) Temporal Changes in Swine Milk Cytokines. CAES Showcase of Excellence NC A&T State University, Greensboro, NC. (Poster presentation) First Place winner.

Improving Cold Stress Tolerance in Leafy Vegetables for Regional Adaptability

Project Director

William Randle

Organization

North Carolina Agricultural and Technical State University

Accession Number

1016489

Improving Cold Stress Tolerance in Leafy Vegetables for Regional Adaptability

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Experiments evaluating the influence of calcium fertility on elevating freeze stress tolerance in lettuce. Five levels of calcium fertility were applied to young lettuce plants that were grown to the five-leaf stage. Plants were standardized at 20 C for 24 hours and then frozen at -4C and -5C. Significant difference were found among cultivars for improved freeze stress tolerance. Increasing calcium fertility also improved freeze stress tolerance. We are waiting on tissue analysis for mineral accumulation to finalize our manuscript for submission. In another study, we began assessing freeze stress tolerance among a wide variety of lettuce cultivars and plant introduction. The aim is to establish the range of variability within lettuce germplasm.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

We have demonstrated that a fertility program has direct effect on a crops ability to withstand freezing. With inadequate available calcium, plants are damaged at -3 C. With adequate available calcium, plants withstand freezing at -5 C. Assessing the variability among lettuce germplasm will provide plant breeders information on parents to include in a breeding program designed to improve plant resilience in light of climate change.

Briefly describe how your target audience benefited from your project's activities.

Going forward, recommendations can be made to growers interested in improving freezing tolerance of lettuce when grown in the transition months leading to winter, and coming out of winter.

Briefly describe how the broader public benefited from your project's activities.

Giving producers of local food information so they can extend their growing and marketing season will benefit consumers who prefer food grown in their area. Lessening risk of production can result in a more stable food supply.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Covid-19 restrictions and Carver Hall renovation once again made our research environment challenging. Because laboratory renovation were implemented from the middle of summer through most of fall, we were unable to complete the freezing experiments and initiate new ones. Most affected was our progress towards evaluating lettuce germplasm for freezing stress tolerance. In addition, with the reductions suffered by HR, we were unable to hire an undergraduate student.

Closing Out (end date 09/07/2023)

U.S. Agricultural Trade and Policy in a Dynamic Global Market Environment
Project Director
Osei-Agyeman Yeboah
Organization
North Carolina Agricultural and Technical State University
Accession Number
1016775

U.S. Agricultural Trade and Policy in a Dynamic Global Market Environment

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

U.S. Agriculture is dependent on the International Market. The U.S. has long been a proponent of developing opportunities for trade through multilateral, bilateral, and regional trade agreements. Recent events, however, including the U.S. withdrawal from Trans-Pacific Partnership (TPP) negotiations and the announced renegotiation of the North American Free Trade Agreement (NAFTA) create uncertainties with respect to their implications for U.S. agriculture. The U.S. decision to withdraw from the Paris Accord creates uncertainties on the environmental front that will affect U.S. agricultural trade, both with respect to the reaction of countries that are markets for U.S. agricultural products as well as our ability to compete through the elimination or reduction of environmental regulations. Although there is much evidence of a change in the stance of the U.S. with respect to international trade, it is important to note that the global market is changing as well. Evidence of this can be seen with Brexit, as Great Britain's vote to secede from the European Union will create the need for renegotiation and modification of numerous trade agreements involving Britain and the EU. Both countries will be forced to develop or renegotiate pacts with the United States as well as with our competitors and customers.

The problem that comes to the fore is that it is often unclear what the implications of these actions will be for agriculture and related interest groups. During the period of 2006-2016, U.S. agricultural exports rose from $70.95 billion to $134.71 billion a 90 percent increase. Imports rose from $65.46 billion to $114.44 billion, resulting in a positive agricultural trade balance that nearly quadrupled from $5.49 billion in 2006 to $20.27 billion in 2016. Given the importance and growth of international agricultural trade for U.S. agriculture and the U.S. economy, there is a need to determine the specific consequences for agricultural trade of these actions mentioned above. These implications include trade creation and trade diversion impacts, as well as price, quantity, and welfare implications for various interest groups, including agricultural producers, agribusiness, consumers, and the environment.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Original project objectives are: 1. Objective 1: Determine the impacts of U.S. and foreign governments' policies, market structures, and regulations on U.S. food and agricultural trade, the economy, and the environment. Objective 2: Determine the impacts of international arrangements and institutions on U.S. food and agricultural trade, the economy, and the environment. A total of four research studies were conducted-one on government policies, and three on trade agreements. Under government policies, spatial regression analysis was applied separately to the annual U.S. state-level food insecurity data from 2015 through 2018, and 2020 to examine the effects of race, region of residency, and poverty particularly due to the COVID-19 pandemic. The results of the analysis suggested that the U.S. food insecurity level was trending downwards between 2015 and 2018 but increased by 33.5% in 2020, obviously due to the COVID-19 pandemic. However, the impact was mild in 2020 probably due to the stimulus and unemployment checks people received through the Care Act. The first study on trade agreements was evaluating the effects of the African Growth Opportunity Act (AGOA) on U.S. Investments Flow into Sub-Saharan Africa. An economic model was applied to a panel data of total foreign direct investments (FDI) to Sub-Saharan African countries as a function of, GDP per capita of the host countries, exchange rate of the host country's currency to the US dollar; and socio-economic variables including political stability index; and dummy variables including language and AGOA participating status, other RTAs. Results suggested that all the AGOA participating Sub-Saharan countries had larger positive net flow of foreign direct investments especially from the U.S. compared to the non-member countries. Study 2 was about determining U.S. Agricultural Growth Under North American Free Trade Agreement. The study employed dynamic shift-share analysis (an econometric tool used by economists to analyze the effect of growth in various industries) to determine the overall U.S. agricultural export performance and that of four major classified agricultural commodity groups (Bulk, Consumer oriented, Intermediate, and Ag-related Commodities) under NAFTA relative to the Rest of the World (ROW). The results indicate that U.S. agricultural exports to NAFTA countries relative to the ROW has grown from a deficit of $26bn to $368bn (1,315%) since its inception in 1994. Lastly, same dynamic shift analysis was used to determine the growth of AGOA member countries' export with regards to the four major classified agricultural commodities. Analyses were performed under pre-

AGOA (1980-2000), post-(2000-2019), and overall period (1980-2019). The results suggested member countries' exports have grown from a deficit of $436 million pre-AGOA to $1,487 million during in post-AGOA. Bulk commodities contributed the most, $754 million, consumer was responsible for $417 million while intermediate, and ag-related contributed $249 million, and $67 million, respectively.

Briefly describe how your target audience benefited from your project's activities.

In consistence with trade literature, all studies that deal with free trade agreements and trade facilitation studies resulted in increased exports. Exporters and shippers have seen increased agricultural exports in both consumer oriented and bulk Free trade agreements with especially countries that do not produce the same commodities are very good for U.S. exports especially Sub-Saharan African countries. Grain and oil seed producers in the mid-west have seen tremendous export growth to Mexico due to NAFTA. Since these agricultural commodities are produced in rural America, increased in exports brings economic development and incomes to these communities. Agribusiness entities, shippers, exporters, and all the businesses in the value chain prosper. It also provides policy makers information to combat anti-free trade groups who hide behind environmental quality to oppose any trade agreement. This includes the unnecessary NAFTA Renegotiations. With regards to government policies, the food security study revealed that, but for the timely intervention of the Care Act checks, most U.S. Households would have faced severe food insecurity and poverty in 2020.

Briefly describe how the broader public benefited from your project's activities.

- Increased in the ability to understand and predict changes resulting from changes in trade agreements.
- Increased in the ability to understand and predict changes resulting from changes in domestic policy.
- More clientele exposure to trade research and information.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

The project's results have been disseminated through several outlets:

1. Three virtual presentations were made in a major conference- Southern Agricultural Economics Association Annual Meetings in Irving Texas, February 6 – 9, 2021;

2. The incumbent presented and submitted his State Report to the President, S-1072 Southern Regional Committee on Agricultural Trade during our fall virtual meeting on December 13, 2021; and 3. All the studies have been published in peer-reviewed journals.

The P.I. plans to continue attending professional meetings, workshops, and collaborate with faculty and researchers in other institutions to learn new about tools and models to be familiar with current trade theories and policy issues that need to be addressed. He also plans to organize workshops and seminars to train graduate students and young faculty. Efforts are also being made to seek other extramural funding from other federal agencies besides the USDA and other state agencies as well as private sources.

Phylodynamics of emerging plant pathogens

Project Director

David Rasmussen

Organization

North Carolina State University

Accession Number

Software and Genetic Models to Analyze Plant and Human Disease

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

The continued emergence and spread of agricultural pathogens presents a major threat to plant and animal health. Understanding the source of novel pathogens and what selective pressures promote or limit their emergence can enable effective control and prevention strategies. Genomic epidemiology, which uses pathogen genomic data to track the spread and evolution of these pathogens can help, but existing methods are geared towards directly transmitted human pathogens. There is therefore a great unmet need for new technologies for tracking the spread of plant and animal pathogens through complex agroecosystems.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Through the support of Hatch funding, my group develops new statistical and computational methods for genomic epidemiology. These methods couple more traditional epidemiological modeling with phylogenetic methods, allowing us to learn about the epidemic and evolutionary dynamics of pathogens from pathogen genomic data. Over the last year, we have extended existing methods to meet several challenges posed by agricultural pathogens, including better models for tracking the spread of plant pathogens through complex agricultural landscapes including non-host environmental reservoirs, better methods for tracking the horizontal exchange of genetic material between pathogen lineages, and better methods for quantifying the fitness effects of mutations and other genetic changes with respect to pathogen transmission potential.

Briefly describe how your target audience benefited from your project's activities.

Our research benefits other infectious disease researchers and the broader scientific community through the implementation of our computational methods in high-quality, open-source software. As an example, our group recently released *Espalier*, a Python package for working with pathogens that can exchange genetic material, including antibiotic resistance genes and virulence factors, through recombination. In addition to software development we provide extensive documentation as well as tutorials to ensure our tools are as accessible and useable by other researchers as possible. *Espalier* and the accompanying documentation can be found here: https://espalier.readthedocs.io/.

Briefly describe how the broader public benefited from your project's activities.

The ability to track the spread of emerging agricultural pathogens will be critical to future control strategies. The models and methods my group has developed for pathogen genomic data have already been used to gain insights into the epidemiology of human pathogens like influenza, dengue and HIV, including identifying major sources and drivers of transmission that can be efficiently targeted for control. By extending these methods to confront the challenges posed by agricultural pathogens, we are providing farmers, industry and government agencies with the computational tools required to translate the information gained from pathogen genomic surveillance into effective and targeted control strategies for plant and animal pathogens.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

One postdoc and two graduate students were trained in part through support of Hatch funding in 2021-22. We have also disseminated our research through a number of publications on genomic methods and their application to major human and agricultural pathogens, including:

1. Guo, F., Carbone, I., & **Rasmussen, D.A.** (2022). Recombination-aware phylogeographic inference using the structured coalescent with ancestral recombination. *bioRxiv*. doi.org/10.1101/2022.02.08.479599

2. **Rasmussen, D.A.**, & Guo, F. (2022). Espalier: Efficient tree reconciliation and ARG reconstruction using maximum agreement forests. *bioRxiv*. doi.org/10.1101/2022.01.17.476639

3. Kepler L., Hamins-Puertolas M., **Rasmussen D.A**. Decomposing the sources of SARS-CoV-2 fitness variation in the United States. *Virus Evolution*, 7(2), 2021. doi.org/10.1101/2020.12.14.422739

4. Dawson, D., **Rasmussen, D.A.**, Peng, X., & Lanzas, C. (2021). Inferring environmental transmission using phylodynamics: a case-study using simulated evolution of an enteric pathogen. *Journal Roy. Soc. Interface*. https://doi.org/10.1098/rsif.2021.0041

5. **Rasmussen D.A.** and Grünwald, N. (2021) Phylogeographic approaches to characterize the emergence and spread of plant pathogens. *Phytopathology*, 111(1) 68-77. doi.org/10.1094/PHYTO-07-20-0319-FI

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

The continued emergence and spread of agricultural diseases presents a major threat to plant and animal health. To address this challenge, NC State researchers are developing new statistical and computational methods to analyze these diseases. In 2021, we developed improved models for tracking the spread of plant diseases through complex agricultural landscapes, created better methods for tracking the exchange of genetic material between disease-causing organisms, and developed better approaches for analyzing the effects of mutations and other genetic changes on disease transmission in plants. We recently released a software package (Espalier) designed to analyze the exchange of genetic materials in plants, including the exchange of genes that affect antibiotic resistance and disease severity, and we provided extensive tutorials to ensure this tool is accessible to other researchers. NC State models and methods have already been used to gain insight into human diseases as well, including HIV, influenza, and dengue fever. This project exemplifies the kind of results being made possible through the North Carolina Plant Sciences Initiative, a strategic university effort aimed at solving grand agricultural challenges.

Microbial Fermentation: A Dynamic Ecology Shaping Nutritional Energetics

Project Director
Vivek Fellner
Organization
North Carolina State University
Accession Number
1013696

Sustainable approaches to managing biodiesel byproduct

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

- The use of biodiesel as an alternative energy source has increased in recent years.
- Glycerol is a major byproduct of biodiesel.
- The greater demand for biodiesel as an alternative energy source has created a large surplus of glycerol.
- Continued use of biodiesel requires efficient and quick disposal of glycerol.
- Traditional uses of glycerol are saturated thereby limiting the production of biodiesel as a sustainable source of energy.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Glycerol (G) was encapsulated at 2.5, 5, 7.5 or 10 % (w/w) with sodium alginate (A) and alginate-chitosan (AC) polymers. Surface morphology and chemical modifications of the beads were evaluated using scanning electron microscopy and FTIR spectra. Encapsulation efficiency was determined at the 5% glycerol inclusion level in two experiments. In experiment 1, 0.5 g of AG and ACG beads were incubated for 2 h at 39oC in pH 2 buffer followed by 24 h in pH 8 buffer to simulate gastric and intestinal conditions, respectively. In experiment 2, 0.5 g of AG and ACG beads were incubated in pH 6 buffer at 39oC for 8 h to simulate rumen conditions. All incubations were replicated four times. Free glycerol content was determined using a spectrophotometer and used to assess loading capacity and encapsulation efficiency. An in vitro experiment with mixed cultures of rumen microbes was conducted to determine effect of encapsulation on microbial fermentation. Data were analyzed according to a complete block design using the MIXED procedure of SAS (SAS Institute, Cary, NC).

Results: For AG and ACG, loading capacity and efficiency were 64.7 and 74.7% and 70.3% and 78.1%, respectively. Based on the FTIR spectra and SEM, ACG treatment demonstrated more intense and stronger ionic bonds. At pH 6, 36.1 % and 29.7% of G was released from AG and ACG, respectively. At pH 2 minimal glycerol was released but pH 8 resulted in 95.7% and 93.9% of glycerol released from AG and ACG, respectively. In vitro microbial data show reduced ($p < 0.05$) fermentation of encapsulated glycerol after 24 h of incubation. The AC polymer provided greater protection in acidic pH with a gradual release of intact glycerol when exposed to an alkaline pH.

The broader contribution of this project and its link to the main objectives is the continued exploration of the microbial fermentation in the ruminant. The significance of the link between microbes in the gut and animal health is increasing and ruminant nutrition is challenged with maintaining a balance in the fermentative processes to maximize efficiency, minimize waste and improve animal performance. Energy is limited in the gut and is released during fermentation of dietary substrates. Main source of energy is the short chain fatty acids (SCFA) that also serve as essential growth factors for microbes. The exact mechanisms are less clear but SCFA regulate the energy status of animals by exerting varying physiological effects in host body tissues. We know little about the microbial fermentations in the gut and their affect on nutrient supply when animals are fed conventional feedstuffs. With the greater introduction of newer byproduct feeds, like glycerol, that are a high energy source, there is a need to better understand the functional role of gut microbes and nutrient exchanges within the gut that will allow us to formulate strategies to enhance nutrient use, minimize nutrient loss and improve energetic efficiency.

Briefly describe how your target audience benefited from your project's activities.

Results were presented to the University of North Carolina, to the NC State department of Animal Science as well as to several Animal Science related industry professionals across the US. The visiting scientist prepared a seminar and shared the results with scientists and colleagues at the National research center in Egypt. A manuscript was prepared and published in the Asian-Australasian Journal of Animal Science. The target audiences for the dissemination of the information from this grant were animal scientists, veterinarians and nutritionists in academia and industry, as well as students in this field, and scientists in the trace mineral and nutrition field as well, regardless of target species.

Briefly describe how the broader public benefited from your project's activities.

- We identified alginate and alginate-chitosan as encapsulating polymers for glycerol.
- Alginate and chitosan are biocompatible, non-toxic and have selective biodegradability.
- We collaborated with the College of Engineering to characterize and validate polymer encapsulation technique.
- Funding was obtained from the National Engineering Council of Egypt.
- Project involved the training of a senior visiting scientist from National Research Council of Egypt.
- The project resulted in a peer-reviewed journal article.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

This project has provided many opportunities for professional development. It allowed the opportunity to provide technical training and professional development of a senior visiting scientist from Egypt. It allowed mentorship and training of students as well as technician. It also provided an opportunity for the PI to engage in professional relationships with collaborators and scientists within the university as well as across other institutions. The project allowed my group to discuss issues and challenges with experts at the national and international level. Undergraduate students received mentoring to do research in the lab, and develop skills and experience in animal research. This is invaluable for students deciding whether graduate school is a viable and attractive career option.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

The use of biodiesel as an alternative energy source has increased the need to sustainably dispose of glycerol, a major byproduct of biodiesel. With the greater introduction of newer byproduct feeds, like glycerol, that are a high energy source, there is a need to better understand the functional role of gut microbes and nutrient exchanges within the gut that will allow us to formulate strategies to enhance nutrient use, minimize nutrient loss, and improve energetic efficiency. To support this effort, NC State researchers have identified natural, biocompatible, non-toxic substances that can be used to capture glycerol, and they have partnered with NC State engineers and the National Engineering College of Egypt to develop and validate methods for this capture. A peer-reviewed journal article discussing the results of this effort has been published, and the project has provided many opportunities for professional development, including technical training of a senior visiting scientist from Egypt and mentorship and training of students and researchers, fostering discussion at the national and international levels, just one example of how our research addresses grand challenges in sustainability.

Nutritional strategies to enhance intestinal health and growth of nursery pigs fed AGP free diets

Project Director
Sung Woo Kim
Organization
North Carolina State University
Accession Number
1013662

Dietary Strategies for Enhancing Nursery Pig Health

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Pig production is largely affected by health status of pigs especially upon weaning. Their intestinal health is compromised upon weaning due to production environments especially in this era of antibiotics free production. Nutritional strategies to enhance intestinal health are in immediate needs. The goal of this project is to investigate various nutritional strategies to reduce intestinal challenges from inflammatory and oxidative stressors which negatively affect intestinal integrity compromising gut barrier functions. Nutritional strategies would include characterization of functional nutrients and development of feeding program.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Four animal research projects have been conducted to test the effects of dietary interventions on intestinal health and growth of nursery pigs without antimirobial growth promotors. Dietary interventions included the addition of specific enzymes to remove harmful compounds in animal feeds, addition of probiotics to reduce the growth of harmful bacteria in the intestine, and use of specialty soy proteins processed to reduce allergenic proteins. The outcomes of the research have been presented at the scientific conferences through the fiscal year period.

Briefly describe how your target audience benefited from your project's activities.

The outcomes of the project have direct relevance to swine production, feed manufacturers, and biotech companies domestically and internationally.

Briefly describe how the broader public benefited from your project's activities.

The outcomes of the research have been presented to 12 international seminars, symposiums, and forums which were delivered in person or virtually. These include China (Animal Science Research Symposium, Nanjing Agricultural University; Pig Symposium, Beijing;), Korea (Brain Korea Symposium, Kyungpook National University; Kyungnam Ag Masters Workshop. Kyeongsang National University; The 6th mBiome International Conference, Yonsei University); Thailands (V-Connect, VIV V-Connect.net); Global webinar (WATTAgNet.com). All presentations for China and Thailands were delivered virtually. All presentations made in Korea were in person. The outcomes of the research projects from the previous fiscal years have been published in peer reviewed scientific journals during this reporting period. These are 10 papers in tier 1 journals in animal sciences. During the report period, the scientific papers published by the PI have been cited 2,128 times (total 16,017 times) according to Google Scholar indicating contribution of the research work to the broader public.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

Pig production is impacted by compromised intestinal health upon weaning, especially in the current era of antibiotic-free production. Innovative nutritional strategies are needed to enhance pig intestinal health. NC State researchers conducted 4 projects to test the effects of dietary interventions on the intestinal health and growth of nursery pigs without the use of antimicrobial growth promoters. The outcomes of this research have been presented at 12 international seminars, symposiums, and forums, and 10 papers outlining the research have been published in tier 1 peer-reviewed scientific journals. These papers have already been cited over 16,017 times, demonstrating that our world-leading faculty are at the forefront of innovation and discovery in animal husbandry.

Tomato improvement for disease resistance, fruit quality and heat stress tolerance

Project Director
Dilip Panthee
Organization
North Carolina State University
Accession Number
1013663

High-Performing Tomato Hybrids

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Tomato is the second most consumed vegetable crop after potato in the USA. However, total US tomato production has decreased over the last few years resulting in increased imports of foreign grown tomatoes and a growing dependance on outside sources as a way of meeting consumer demand. Drought, climate change, supply chain issues, increased costs of fuel and fertilizer, pests and disease all contribute to the decrease in tomato production. Developing high yielding tomato varieties is one of the solutions to address this issue.

There are several foliar and soil-borne bacterial, fungal and virus diseases affecting tomatoes. The development of resistant varieties using a conventional and molecular breeding approach would not only make the crop production economically beneficial but also help to keep the environment clean by reducing the use of pesticides for tomato crop management. There is a huge demand for high quality tomatoes in the marketplace. We are aiming to develop tomato varieties resistant to various diseases with improved fruit quality.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

To address the above problems, the following activities were initiated:

Replicated variety evaluation trials: Conducted advanced stage trial towards the release of tomato hybrids. Any outcome from this trial will address the objective of releasing the variety, which is the final stage of breeding.

Evaluation of tomato lines for Bacterial wilt resistance. The activity was repeated to refine the selection and measured the yield. Some of the lines are very good for yield and quality but still not good enough to compete with regular breeding lines to be used as parents for the development of hybrids.

Evaluation of tomato hybrids, and breeding lines for EB and LB under organic and conventional conditions to identify the resistant genotypes for organic conditions. Multiple genotypes were identified as suitable, performing better than control for organic as well as conventional production system. The release proposal is ready for release.

Screening of tomato lines for BS was conducted to identify the lines resistant to the BS, particularly large-fruited tomato lines. Multiple lines were found resistant to the BS. We are going to evaluate for yield performance and submit the release proposal this year.

Screening tomato lines for heat stress tolerance: Heat stress is one of the significant abiotic stresses that impact the growth and development of plants. Tomato (*Solanum lycopersicum* L.) is susceptible to high temperatures. As climate change has become a looming threat to agriculture production, it has been a more sensitive issue for tomato production. It is estimated that there may be a rise in temperature by 1 to 3.7°C by the end of the 21stcentury in 100 years (IPCC, 2014). Screening tomato lines for heat stress tolerance and investigating its genetics for heat tolerance is routine activity. We had a relatively small trial at Piedmont Research Station, where average day and night temperatures are higher than critical temperatures. This study will identify the tomato lines tolerant to high temperatures with good quality.

Briefly describe how your target audience benefited from your project's activities.

At least three tomato hybrids that can potentially be released based on multi-year data and overall performance were developed and identified.

At least five breeding lines that can be used as parents, and eventually can be released were identified. Their performance can be verified, and yield data can be measured.

Disease resistance including Bacterial speck, Bacterial wilt, and Late blight resistant breeding lines were identified, and can be released by measuring the yield data.

Heat stress tolerant lines are at early stage of selection. We will have to make further selection. This will refine the selection.

Information was shared with stakeholders. Stakeholders had a chance to see the tomato hybrids, and tomato breeding lines resistant to the BS during the tomato field day in Aug. Some of the tomato growers as well as tomato industry have shown interest in my hybrids and asked for seeds for trials.

Seeds have already been provided based on the material transfer agreement (MTA), particularly with the seed company. While there is a growing interest in multiple tomato breeding lines and hybrids developed from NC tomato breeding program, we still have to see the results from those seed companies.

Briefly describe how the broader public benefited from your project's activities.

Tomato growers have been using tomato hybrids developed by NC State for a long time. Our current research will contribute to these ongoing impacts by developing additional hybrids that increase yields and in turn increase profitability for growers and reduce purchase price for the consumer. This research can also reduce our nation's dependence on foreign import of tomatoes. Tomato hybrids that are disease resistant not only save growers money in terms of reduced production costs but also the use of resistant hybrids have a positive impact on the environment. The reduction in pesticide use can have a long-term impact on the quality of our soil and water as well as an impact on human health.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

No major issues have been observed so far. We can implement the proposed research activities smoothly as planned before.

Publications

1. **Panthee, D.R.** (2021). 'Mountain Regina': Multiple disease resistant fresh-market hybrid tomato and its parents, NC 1LF and NC 2LF. *HortScience*, **56**: 736-738; https://doi.org/10.21273/HORTSCI15824-21.

2. Zhang, J. and **Panthee, D.R.** (2021). Development of codominant SCAR markers for the detection of the *Pto*, *Tm22*, *I3*, and *Sw5* genes in tomato (*Solanum lycopersicum* L.). *Plant Breeding*, **140**: 342-348: **DOI:** https://doi.org/10.1111/pbr.12902.

1. **Panthee, D.R.** Zhang, J., and Piotrowski, A. (2021). Evaluation of tomato breeding lines for Bacterial speck resistance. *HortScience* 56 (9):S127.

2. **Panthee, D.R.,** Kressin, J., & Piotrowski, A. (2021). Identification of potential rootstocks for tomato grafting from bacterial wilt screening trials in North Carolina. *II INTERNATIONAL SYMPOSIUM ON VEGETABLE GRAFTING*. https://doi.org/10.17660/ActaHortic.2021.1302.23.

1. **Panthee, D.R.,** and Piotrowski, (2021). Tomato variety replicated yield trials 2020. Tomato Field Day. Aug 9, 2021, Mills River, NC.

2. Piotrowski, A. and **Panthee, D.R.** (2021). Screening tomato for Late blight resistance. Tomato Field Day, Aug 9, 2021, Mills River, NC.

3. Zhang, J., Piotrowski, A. and **Panthee, D.R.** (2021). Breeding tomatoes for Bacterial speck resistance. Tomato Field Day, Aug. 9, 2021, Mills River, NC.

4. **Panthee, D.R.**, Kressin, J. and Piotrowski, A. (2021). Identification of potential rootstocks for tomato grafting from bacterial wilt screening trials in North Carolina. *Acta Horticulturae,* **1302**: 169-177: DOI 10.17660/ActaHortic.2021.1302.23.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

Tomatoes are the second most consumed vegetable crop after potatoes in the US. The development of high-yielding varieties to combat drought, climate change, pests and diseases, and supply chain issues is a way to meet consumer demand and reduce dependency on tomato imports. NC State researchers have developed and identified 3 high-performing tomato hybrids that can potentially be released based on multi-year data and overall performance. Researchers also identified at least 5 breeding lines that can be used as parent plants and eventually released, as well as lines with resistance to key pathogens. Stakeholders were given the opportunity to see the tomato hybrids during a field day, and some growers and tomato industry stakeholders were provided with trial seeds. This research is contributing to the development of additional hybrids that increase yields, increase profitability for growers, reduce prices for consumers, and reduce dependence on imports. Tomato hybrids that are disease resistant not only reduce production costs but also reduce pesticide use, generating positive long-term impact on soil and water quality and human health. Through this and similar breeding efforts, NC State is feeding our future, growing our economy, and empowering growers and plant scientists to overcome grand challenges.

Translational approaches to improve management strategies for cucurbit and sweetpotato diseases in North Carolina

Project Director

Lina Quesada

Organization
North Carolina State University
Accession Number
1013382

Improved Management of Cucurbit and Sweetpotato Disease

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Issue: Cucurbit downy mildew caused by the oomycete pathogen *Pseudoperonospora cubensis* is a devastating disease in cucurbit crops and the number one threat to production, especially in cucumber. This disease used to be controlled with host resistance in cucumber and limited fungicide applications in other cucurbits. However, in 2004 a pathogen population shift resulted in failure of cucumber resistant varieties and previously effective fungicide products. Now, the disease has to be managed with frequent and expensive fungicide applications to prevent devastating yield losses. The pathogen is prone to quickly developing fungicide resistance, thus, *continued monitoring and identifying novel management strategies, is critical to producers.*

Issue: Sweetpotato black rot caused by the fungal pathogen *Ceratocystis fimbriata* caused a devastating epidemic in the United States in 2015-2016. I am the only sweetpotato extension pathologist, therefore the entire US industry looked at my program for guidance through this crisis. The pathogen used to be successfully controlled using cultural practices, however, a changing climate and use of new sweetpotato varieties through the years have made those cultural practices insufficient to manage black rot. *Halting the epidemic and subsequently developing integrated management strategies for sweetpotato black rot was urgent.*

Issue: The oomycete pathogen *Phytophthora capsici* can cause root, crown, and fruit rot in cucurbit crops. This pathogen is very aggressive resulting in total field losses when the weather is favorable, host resistance is not available, it can become resistant to fungicides, and it can infest irrigation water from surface water sources. *Several cucurbit and pepper producers have reported as high as 80% losses due to this pathogen in spite of having excellent practices as far as cultural options and fungicide programs.* Better understanding of what was causing these extreme losses was needed.

Issue: The root-knot nematode *Meloidogyne enterolobii* was introduced into North Carolina and in recent years it has had a negative impact on the sweetpotato industry due to yield losses and market opportunity losses after quarantines were enacted to contain it. *Developing short-term disease management recommendations for growers was critical to maintain customer confidence in our industry, as well as interfacing with regulatory agencies in the state and beyond to minimize negative trade impacts.*

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Approach: My program has worked closely with cucurbit growers, cucurbit packers, extension agents, crop consultants, seed companies, and chemical companies to improve management of cucurbit downy mildew. My efforts have resulted in development of a field biosurveillance system that provides host risk and fungicide resistance information for precision management. We are state collaborators for the Cucurbit Downy Mildew IPM PIPE national alert system and host sentinel plots on a yearly basis for pathogen monitoring. *Our efforts have been so successful that growers and packers continue to fund our research and to date have provided $400,000 for downy mildew research and extension. In addition, they have established an endowment for our lab.*

Approach: We provided strong leadership to the sweetpotato industry during the epidemic by organizing numerous emergency meetings and quickly securing an emergency Section 18 label for an effective fungicide to stop the disease. *The NC sweetpotato industry was so impressed with our efforts that they provided an unsolicited and unprecedented $500,000 donation to support activities in my program.* That donation allowed us to dive into developing integrated strategies to manage the disease through years of research and extension efforts. My program was able to determine that the pathogen could be transmitted through cuttings even when these were taken using best practices. This resulted in a shift in the production system by implementing fungicide applications at key points to reduce disease levels. Growers and packers have now updated and effective recommendations to manage black rot in seed production, production fields, and postharvest. We have established strong collaborations with chemical companies and IR4 and have secured registrations for five new fungicides in sweetpotato (Mertect, Stadium, Aprovia Top, FoodDefend, Miravis Top) with two more pending (Graduate A, Uvasys). The current emergency I am working on for the industry are trade barriers to our sweetpotato exports due to arbitrary revisions to pesticide import tolerances by the European Union. My collaborative efforts in this regard with the

industry, the Foreign Agricultural Service, IR4, and the European Commission resulted in a $1.5 million FAS-TASC grant being funded to work on these trade barriers to continue the expansion of NC sweetpotato exports. More importantly, these efforts resulted in a revision for import tolerances for thiabendazole (Mertect) that will go into effect in 2022, allowing NC sweetpotato exporters to control postharvest disease in a cost-effective and safe manner, while maintaining an expanding NC sweetpotato exports into Europe and beyond. *Again, in support of my efforts regarding postharvest sweetpotato pathology and exports, the NC sweetpotato industry donated a mini-sweetpotato packing line housed at the Central Crops Research Station for my research*.

Approach: After visiting with affected growers and extension agents, we suspected surface water used for irrigation was infested with *P. capsici*. We took water samples and determined that this was correct. We worked closely with each grower to develop management strategies compatible with their situation. In some cases a sand filter with chlorination was implemented, in other cases growers switched to well water for irrigation. We also suggested updated cultural practices for water management such as using raised beds, plastic mulch, and training vines when possible. We also performed fungicide efficacy trials and provided updated fungicide recommendations to maximize the effect of chemical control. *One grower in particular was so grateful for our interventions that he donated us an irrigation reel and a sprayer to use in our research trials*.

Approach: Even though I have no nematology training and due to the retirement of our nematologist, I took a leadership role in this issue for four years while a new nematologist was hired. During those years, I focused on quickly deploying on-farm trials to identify chemical control options that growers could implement in the short-term to prevent yield losses. *My program developed what are now the gold standard recommendations for management of Meloidogyne enterolobii in sweetpotato* (Telone II, Velum Prime). I also identified two effective experimental products that pending approval of the Environmental Protection Agency, will be effective alternatives or complementary non-fumigant nematicide applications.

Briefly describe how your target audience benefited from your project's activities.

Impacts: North Carolina is the second largest producer of pickling cucumbers in the United States. According to the National Agricultural Statistics Service, North Carolina has approximately 8,499 acres of cucumbers, 1,509 acres of melons, 2,514 acres of pumpkins, 2,531 acres of squash, and 5,498 acres of watermelon. Through our efforts, we save growers approximately 4-6 fungicide sprays per year. Since fungicide sprays can be about $30 -$50 per acre, per application, per product depending on the product, *our efforts would translate into a $2.5 to $6 million in savings yearly for NC cucurbit growers alone*.

Impacts: Our timely efforts reduced losses from 40% to 5% in NC due to the disease according to the NC Sweetpotato Commission. The National Agriculture Statistics Service indicates North Carolina has approximately 86,000 acres of sweetpotato ($331.7 million value), and *our efforts prevented an estimated $116 million in losses for NC sweetpotato grower and packers*. We expect that the revision of thiabendazole (Mertect) import tolerances for 2022 exports will have a significant impact on NC sweetpotato exports (millions), but we do not have those specific monetary figures at this time.

Impacts: Our recommendations reduced fruit losses from 80% to 20% for two of the largest watermelon and squash growers in the state. According to the National Agriculture Statistics Service, North Carolina has approximately 8,499 acres of cucumbers ($22 million value), 1,509 acres of melons ($8.4 million value), 2,514 acres of pumpkins ($6.8 million value), 2,531 acres of squash ($7 million value), 5,498 acres of watermelon ($30.6 million value), and 2,635 acres of peppers ($26 million value). All of these hosts are susceptible to *P. capsici*, but in the specific cases of the watermelon (300 acres) and squash growers (120 acres), *this translated into estimated NC grower savings of almost $1 million and $200,000 in watermelon and squash, respectively*.

Impacts: The National Agriculture Statistics Service indicates North Carolina has approximately 86,000 acres of sweetpotato ($331.7 million value). We provide 70% of the seed used in other sweetpotato regions in the United States and Canada, so the entire industry is heavily dependent on North Carolina sweetpotatoes. *Having effective recommendations allowed producers to maintain yields to fulfill seed, fresh market, and processing contracts*. The nematode continues to be a threat, and while our efforts helped with yield losses, they cannot successfully eradicate the nematode. With the 2019 quarantines, ongoing and drastic research and extension efforts will be needed to significantly reduce nematode levels and protect the reputation and long-term viability of the NC sweetpotato industry.

Briefly describe how the broader public benefited from your project's activities.

North Carolina provides a significant portion of the vegetable produce in the United States. Our efforts in disease management on North Carolina vegetable crops have contributed to food security in the US.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Training: during this period, 15 undergraduate students, 6 graduate students, 3 postdoctoral researchers, and 4 technicians were trained in vegetable pathology research and extension.

Dissemination of results: results were disseminated in 12 research journal articles, 4 book chapters, 18 oral research presentations, 10 poster research presentations, 21 extension journal articles, 2 production guides, 14 oral extension presentations, 5 poster extension presentations, and 5 pest alerts.

Continuation: we will continue our efforts in performing research and extension on disease management of cucurbit and sweetpotato crops in North Carolina.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

NC State has developed a biosurveillance system for precision management of the cucurbit downy mildew pathogen, and host annual disease monitoring plots. This has inspired growers and packers to provide $400K to date for downy mildew research and to establish a laboratory endowment. Researchers also determined that sweetpotato black rot can be transmitted through cuttings even when they are taken using best practices, resulting in a shift in fungicide applications that reduces disease. Researchers also established collaborations with chemical companies and IR4 to secure registrations for 5 new fungicides for sweetpotato. NC State research in pickling cucumber disease prevention saves growers an estimated $2.5 to $6 million annually by providing best practices that reduce fungicide spray volume. These are the kinds of results being made possible through the North Carolina Plant Sciences Initiative, a strategic university effort aimed at solving grand agricultural challenges.

Consumer Horticulture

Project Director
Lauren Hargrave
Organization
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Accession Number
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Beekeeping

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Many of the crops we rely on need pollination services provided by domestic bees for good yields and quality. While the disappearance of the honeybee probably wouldn't be enough to collapse food systems, it would undoubtedly affect the outcome and quality of crops North Carolina farmers rely on for profitability. In recent years honeybees have gotten a lot of attention from the public. These insects are vital to our society, providing multiple products from their hives and generating enormous value in their pollination services. Many people find this insect so fascinating that they want to learn how to keep honeybees themselves. However, beekeeping can be very difficult. There are many obstacles to becoming a beekeeper and few training opportunities available.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Beginners Beekeeping School was provided in three counties. One county initiated a beekeeping club. Five counties (Robeson, Rowan, Stokes, Vance, & Rowan) completed various beekeeping trainings, totaling 1,052 hours and 138 participants.

Briefly describe how your target audience benefited from your project's activities.

The Columbus County Farmers Market was contacted by the Columbus County agriculture and natural resources (ANR) agent, who asked if some shelters and amenities could be made available for a bee school. The market managers agreed, and an agreement was signed. The Columbus County Beekeepers Club held a three-day school with 17 students. Master Beekeepers were there to teach and show hands-on displays to help the students learn. All participants successfully completed the classroom training and returned in June to perform hive inspections and demonstrate their knowledge and skills. All of them passed and were certified as beginning beekeepers in North Carolina.

The Extension ANR agent is the Beekeeper's Association liaison for the Rowan County Beekeepers. Based on the beekeepers' concerns about the lack of youth engagement with honeybees, they established an "incubator" program and beekeeping club that raises awareness and engages youth in beekeeping through hands-on activities. A grant proposal was submitted through the Whole Kids Foundation through Cooperative Extension on behalf of the Beekeepers. In December, Rowan County Extension was notified they had been awarded the $1,500 grant. The hives will be used as an outreach and education tool for the community. With the funding, we hope that three to four interested children will become 4-H Apiculturists in the spring of 2022. The goal will be for children to start their hives at home using their knowledge from their time as 4-H Apiculturists.

In 2021, the Union County ANR agent partnered with the Union County Beekeepers Association to provide three Beginner Bee Schools. These schools consisted of seven sessions where participants learned about honeybee biology, seasonal management, and hive equipment. These sessions also gave students a chance to network with other aspiring beekeepers and experienced beekeepers. This network is beneficial for novice beekeepers as they encounter challenges. These classes trained 138 students. Participants can use what they learned to start keeping bees. The classes also helped some participants realize that beekeeping is not a good fit for them because of the time and dedication required. While they will continue to be advocates of honeybees, they won't become beekeepers. Both of these scenarios save time, money, and frustration as people continue their support and interest in honeybees.

Briefly describe how the broader public benefited from your project's activities.

N/A

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

N/A

GAP & FSMA Compliance Education Program

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Foodborne illnesses killed 120 Americans and sickened 25,606 in 2018, according to the Centers for Disease Control and Prevention. All food products are coming under increased scrutiny by consumer groups and government agencies. With the fast growth of the fruits and vegetable industries, there is an increased risk of contamination from various sources. Contamination control programs do not start and stop at the produce handler. Prevention steps must begin on the farm. Current technologies cannot eliminate all potential food safety hazards, however, utilizing the Good Agricultural Practices (GAP) and Food Safety Modernization Act (FSMA) allows farmers to minimize the risk of contamination.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

To further ensure the safety of fruit and vegetable crops in North Carolina, Extension farm specialists and county agents in 2021 conducted food safety training for farmers in four counties (Robeson, Warren, Vance, and Columbus). The specialist utilized the Food and Drug Administration Produce Safety Alliance Grower Trainer curriculum and followed the eight principles of Good Agricultural Practices to conduct the training. The eight principles are:

1. Prevention of microbial contamination.

2. Implementation.

3. Microbial contamination

4. The water source and its quality.

5. Operations that use manure.

6. Work hygiene and sanitation practices.

7. Adherence to all applicable local, state, and federal laws and regulations, and,

8. Accountability, monitoring, and trace back.

The instructor engaged the participants with an activity involving applying sound management principles to produce healthy and safe agricultural products for human consumption without a?ecting the environment and the general public's health. Additional farm visits, one-on-one activities, and demonstrations covered irrigation system management, post-harvest water management, water sampling, Ph testing, packing house sanitation, field sanitation, and animal control.

Briefly describe how your target audience benefited from your project's activities.

Good Agricultural Practices and the FSMA training require face-to-face engagement to understand the principles fully. Despite the pandemic, we reached 32 farmers with our program through four training sessions and five site visits. As a result of our work:

31.2% (10) farmers stated that they would adjust their farm practices to meet USDA GAP certification and FSMA complaints

100% of the participants stated they were GAP and FSMA ready, meaning they could now properly practice GAP and FSMA.

15.6% (5) farmers promised to become GAP certified.

The participants viewed the program as an essential part of their production process and efforts to make their products safe.

Briefly describe how the broader public benefited from your project's activities.

N/A

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

N/A

On Farm Demonstration

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Many small, beginning, limited-resource, and socially disadvantaged farmers apply for and receive cost-share from the USDA Natural Resource Conservation Service (NRCS) to build high tunnels for farm food and flower production. The program requires the farmers to actively produce a crop in the high tunnel to retain their cost-share amount. These farmers often do not know how to be profitable producing in a high tunnel since it is quite different from traditional fruit, vegetable, and flower cultivation. Many beginning farmers receiving the high tunnel cost-share have not grown anything since childhood.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Twenty-seven individual site visits to 18 different farmers were made in Beaufort, Bertie, Camden, Currituck, Halifax, Martin, Pasquotank, and Warren counties. These farmers were small, beginning, limited resource and socially disadvantaged growers who had recently installed or were considering installing a high tunnel. The N.C. A&T High Tunnel Guide was provided to each of the 18 growers and to 15 additional growers upon request to improve their knowledge of high tunnel installation and production. Initial site visits included thorough walk-throughs and discussion of current high tunnel sites and planned site, and discussion of growing practices. During the farm visits, training was provided on individual operations to address farmers' concerns and shortcomings on a case-by-case basis. The sessions included information on high tunnel site selection and design, soil sampling procedures, interpretation of results and amendments, selection of high tunnel crops and varieties, installation of drip irrigation and fertigation, planting practices and trellising, and marketing strategies. Information gleaned from these visits will be used to design future group programming.

Briefly describe how your target audience benefited from your project's activities.

Seventeen growers involved with our high tunnel fruit, vegetable, and cut flower production visits have implemented suggested practices. The growing season started in 2021, so results are not yet available. However, growers have already implemented some methods such as removing crop plant debris and weed management. These practices limit the spread of plant disease from crop plant debris and lessen the weed pressure in high tunnels by removing weeds and weed seed before they spread. The demonstration of drip irrigation system installation is also proving to be beneficial to the farmers since it provides a constant and reliable way to deliver water to growing plants.

The small farms specialist for Northeastern North Carolina worked with one high tunnel vegetable grower in Bertie County to submit a grant proposal in December 2021 for additional equipment to improve their high tunnel. This producer received $9,000 from the Ag Prime UMO (Tobacco Trust Fund) to enhance their high tunnel's ventilation, irrigation, and other aspects in 2022.

Briefly describe how the broader public benefited from your project's activities.

N/A

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

The Small Farms Northeast Specialist has identified four sites for demonstration plots that will be used for field events in 2022. They have also been working with Currituck County to install a demonstration high tunnel at the County Extension Center, which is expected to be finished in 2022.

Organic and Sustainable Agriculture

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

U.S. agriculture has involved heavy chemical inputs such as the intensive use of chemical fertilizers and pesticides, making it unsustainable. The trending local food movement provides small and limited resource farmers with great opportunities to transition conventional production into organic and sustainable production, especially with specialty crops such as vegetables and small fruits. Organic and sustainable farming practices help small, limited-resource farmers improve the health of their farmland, increase their profits, and improve the quality of their communities.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

In 2021, the N.C. A&T horticulture specialist continued the Tomato Organic Management and Improvement project. Twenty-two organic tomato cultivars and advanced selections were tested on the N.C. A&T University Farm for growth, disease resistance, yield, and fruit quality.

The horticulture specialist also conducted organic cucumber cultivar evaluations for the second time. Twelve seedless, greenhouse-type cultivars (Corinto, Diva, Kalunga, Katrina, Picolino, Poniente, Socrates, Sun Mix, Suyo Long, Tasty Jade, Tyria, and Unagi) were tested in an organic high tunnel. Yield, fruit quality, and disease-resistance data were collected and analyzed. Results will be shared with farmers and Extension agents in a high tunnel cucumber production guide that is currently in production.

N.C. A&T continued the Diverse Native Hedgerow for Pollinators project. Throughout the growing season, diverse plants with overlapping and successional blooms provide nectar, pollen, shelter, and nesting sites for pollinators and natural enemies (predators and parasitoids) of crop pests. This demonstration project offers learning opportunities for both farmers and agents on how to use nature to solve pest and production challenges.

Additionally, the NC Sustainable Agriculture Research and Education (SARE) program offered scholarships for professional development to Extension personnel and agricultural professionals. SARE sent 19 Extension agents to the Carolina Farm Stewardship Association Sustainable Agriculture Conference and provided conference support for 17 presenters who participated in an interactive virtual conference. In accordance with the program design, scholarship recipients will use the knowledge and skills learned in their Extension work and report impacts nine months after the event. Those results are not yet available.

Briefly describe how your target audience benefited from your project's activities.

Organic strawberries usually bring farmers more than $20,000 per acre in open field systems and about $25 per acre in low tunnels and high tunnels ($14,400 for a 30-foot by 96-foot high tunnel). Organic produce sells at prices 40% or more than prices for conventional produces at direct market. The specific income received by farmers will be determined by their sales.

Small, limited resources farmers benefited from this program by applying knowledge learned about technology in organic and sustainable farming or by switching to organic production. Extension agents benefited from the scholarship opportunities, and our applied research and demonstration projects gave them knowledge about new tactics in organic and sustainable agriculture, which enables them to serve their clientele better.

Briefly describe how the broader public benefited from your project's activities.

N/A

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

N/A

Plasticulture Rental and Cashback Program

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Plasticulture production has been proven to increase yield and extend the growing season for small farmers. However, plasticulture equipment is expensive and beyond the reach of many small farmers. Due to the high cost of purchasing plasticulture equipment, small farmers do not routinely take advantage of plasticulture's production benefits. Those benefits include earlier harvests, better weed control, enhanced watering efficiency, and better plant nutrition through targeted nutrients applied through drip irrigation lines. NC small farmers who adopt plasticulture production have the potential to increase their yields and profits.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

To make plasticulture production more accessible, NC A&T created the Plasticulture Rental/Cash Back Program. Equipment is provided strategically at County Extension Centers across NC. The rental net cost to the farmer is $25/day. The Plasticulture Rental/Cash Back Program trained extension agents to better assist small farmers in their respective counties with plasticulture operations.

The plasticulture program operated under COVID-19 guidelines for the entire 2021 calendar year. These additional steps and checkpoints require farmers to certify they are not currently sick, have not to their knowledge been exposed to COVID-19, will practice social distancing in their plasticulture operations, will wear face masks when engaged in plasticulture operations, and will clean and sanitize the plasticulture equipment before returning it to the pickup/dropoff location. To further ensure the safety of all involved in the rental process, Extension agents at the return locations are required to clean and sanitize the equipment upon return. These changes were implemented to ensure the safety of farmers and N.C. A&T staff at the renting county Extension centers and the University Farm. Though restrictive, this allowed the program to continue operating during the pandemic.

Briefly describe how your target audience benefited from your project's activities.

Thirteen additional farmers in five NC counties were able to utilize this valuable program to expand and diversify production on farms ranging from two to 100 acres. These farmers deployed plasticulture on 24 acres of production area, producing crops such as vegetables, hemp, and berries. The cost to the small farmers totaled $550, saving them $18,945, which would have been the cost of purchasing their own equipment. Four farmers were first-time participants in the N.C. A&T Plasticulture Program, while three farmers reported this was the first time they had used plasticulture as a production method. Five farmers utilized organic farming principles, while another five were conventional producers. Without the continued operation of the program, it is problematic whether these farmers would have taken advantage of the increased production plasticulture offers due to the high initial cost of purchasing plasticulture equipment.

To reduce the economic risk and increase on-farm income for small and limited resource farmers, the N.C. A&T Agriculture and Natural Resources agents in Duplin and Sampson counties coordinated rental of the following equipment:

- Nolts RB436 plastic layer for 3-foot plastic (retail cost: $1,43).
- Nolts RB446 plastic layer for 3-or-4-foot plastic (retail cost: $2,035).
- Rain-Flo 1800 mulch liner (retail cost: $2,035).

As a result of educational outreach and technical assistance from the small farm agent, six limited-resource, small producers avoided a total of $17,767 of additional debt. They earned a combined total gross income of $45,290 by growing specialty crops on six acres of black plastic.

Briefly describe how the broader public benefited from your project's activities.

N/A

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

- 8 agent trainings: 92 attendees
- 4 farmer trainings: 59 attendees
- Publication produced- Troubleshooting Job Aid for the RB436/RB448 Plastic Mulch Layers and the 1800 Plastic Mulch Liner
- Publication produced- N.C. A&T Plasticulture Rental Cash Back Program for Small Farmers Brochure

The agents polled noted the value of the quarterly plasticulture updates and how they used them to keep their farmers apprised of the latest developments in plasticulture. Small farmers reported learning valuable information on developing degradable mulch materials and addressing environmental concerns. They also expressed a strong desire to learn more about degradable mulch materials. As a result, the Plasticulture Program will work with industry partners, plastic mulch vendors, and small farmers to conduct testing of these materials at the University Farm in 2022. Results and recommendations from the tests will be shared with small farmers in the fall. The program will continue to offer quarterly plasticulture updates.

It is anticipated that as degradable mulch technology advances and the cost of materials decreases, more small farmers will adopt them. A positive environmental impact should result from using degradable mulches, as less plasticulture waste ends up in landfills.

Small Farm Leadership 360 Initiative

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

In today's rural North Carolina, small farmers and beginning farmers face complex challenges related to sustaining their farm businesses in a rapidly changing and competitive environment. These limited-resource small farmers face various issues, including establishing the most effective business entity, understanding best farm practices, developing essential accounting/record keeping skills, and succession planning. They also struggle with marketing their products and services, understanding tax law, and securing needed financial resources, such as loans and grants to sustain their farm operations and family unit. Thus, they need support in developing business decision-making skills.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

A team was established to identify the needs and challenges faced by small, disadvantaged farmers related to sustaining their small farm businesses. Listening sessions were conducted in four locations in eastern North Carolina in 2019. A team of professionals interviewed farm operators, community leaders, county Extension staff, and local educators. As a result of this effort, a set of recommendations were developed. The first recommendation was to create a special small farm task force to provide leadership in developing and implementing a series of educational programs to address the needs of this audience. The Small Farm Task Force was appointed in January 2021. The group outlined an initiative and branded it "Small Farm Leadership 360." This program was promoted in 17 counties in eastern North Carolina. The initiative included four program modules, designed as a result of the listening sessions, covering U.S. production agriculture, marketing opportunities for small farmers, farm cooperatives, and best practices in agricultural production.

Briefly describe how your target audience benefited from your project's activities.

The task force was in development in 2021, so data is currently being collected.

Briefly describe how the broader public benefited from your project's activities.

N/A

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

The first module of the Small Farms Leadership 360 Initiative was conducted in February 2022 and covered legal issues, including land leases, business entity formation, heir property, succession planning, accounting, recordkeeping, taxes, federal grants, and loan programs. The module also addressed the function and operation of farmers markets in the state.

During the remainder of 2022, the other three modules will be facilitated to meet the needs of small, limited-resource farmers.

2021 Small Farms Task Force Meetings:

January 12, 2021o 2 hours

Location: Zoom

Participants: 3 (administrators)

February 4, 2021o 2 hours

Location: Zoom

Participants: 8

Critical Issue

Protecting Environmental and Natural Resources

A Carbon-Negative Bioeconomy: Leveraging Bioprocess Synthesis, Applied Engineering, and Techno-Economic-Life Cycle Analysis to Utilize and Sequester Carbon Dioxide

Project Director
William Sagues
Organization
North Carolina State University
Accession Number
1026204

Insights to Support a Carbon-Negative Bioeconomy

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

To meet the stringent climate targets set forth by the Intergovernmental Panel on Climate Change (IPCC), the United States is expected to sequester 1 Gt-CO2 per year in 2050 and 3 Gt-CO2 per year in 2100 (1 Gt= 1 billion metric tons). To meet such ambitious targets, research, development, and demonstration of CO2 capture, utilization, and sequestration (CCUS) technologies must rapidly accelerate. For the US to realize this potential, it must transition from a circular bioeconomy to a “carbon-negative” bioeconomy, wherein bioprocesses and bioproducts result in a net reduction of atmospheric CO2.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

The primary goal of this project is to develop carbon-negative bioprocesses of relatively high technology-readiness-level (TRL) that integrate with existing industrial and agricultural operations, thereby providing near-term, low-risk, and large-scale biological carbon capture, utilization, and sequestration opportunities. Experts in synthetic biology, chemical catalysis, soil

science, bioprocess engineering, techno-economic analysis, life cycle assessment, and environmental policy will work together to design, develop, experiment, model, and assess four bio-CCUS technologies. The technologies include multiple avenues for biogenic CO2 utilization and sequestration, including mineralization, geologic storage, graphite synthesis, and microbial fixation. In FY21-22, I participated in research grants worth over $9M ($1.4M at lead PI) aimed at achieving the aforementioned goal. From these projects, I have established preliminary data to make significant impacts in enabling carbon dioxide removal in the ethanol fermentation, animal protein, and pulp and paper industries, to name a few.

Briefly describe how your target audience benefited from your project's activities.

My target audience is broadly defined as stakeholders in the industrial bioeconomy. In FY21-22, I provided my stakeholders with over 10 presentations at conferences and workshops and 5 publications. Specifically, my lab group is in the early stages of developing several carbon-negative bioprocesses, which I have disseminated to stakeholders in a variety of ways. Several of my current and pending research projects have close ties to large corporations, including Novozymes, Rayonier, and Sunrock, thereby demonstrating the potential for significant, near-term impact. In addition, I am mentoring 9 graduate students (5 as chair/co-chair) to ultimately become leaders in the transition to a carbon-negative bioeconomy, which also benefits my target audience.

Briefly describe how the broader public benefited from your project's activities.

In FY21-22, the broader public has benefited from my research projects through a variety of ways, including a multitude of presentations and publications that were made publicly available. For example, I published a repository of data from the scale-up of an advanced biorefining technology, which had never been done before. Typically, such data are concealed from the public due to proprietary reasons. However, I worked with Oak Ridge National Laboratory to unlock the data and post publicly via GitHub. These data are already being used by several large bioprocessing companies, including Rayonier and Meati, to scale-up their own biorefining technologies. In addition, I participated in several Department of Energy grant development and review workshops, wherein I helped to allocate public taxpayer dollars to research projects with significant potential for success. Finally, I am co-leading the American Society of Agricultural and Biological Engineers's Circular Bioeconomy Systems Initiative, wherein I am responsible for developing public materials to disseminate the importance of transitioning to a circular bioeconomy.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

To support meeting stringent requirements established by the Intergovernmental Panel on Climate Change (IPCC), the US must transition to a “carbon-negative” bioeconomy in which processes and products result in a net reduction of CO2 in the atmosphere. NC State researchers have participated in over $9 million worth of grants aimed at achieving this goal and have already established preliminary data to enable removal of carbon dioxide in several industries, including animal protein, pulp, and paper. Over 10 presentations were delivered to stakeholders at conferences and workshops, and 5 publications were produced. NC State researchers are in the early stages of developing several carbon-negative bioprocesses, and several current and pending projects have close ties to large corporations (e.g., Novozymes, Rayonier, Sunrock), demonstrating their potential for significant, near-term impact. NC State has also partnered with the Oak Ridge National Laboratory to make crucial data available to the public, and these data are already being used by large bioprocessing companies (e.g., Rayonier, Meati) to scale up their biorefining technologies. This is just one example of how NC State’s cutting edge, solution-driven research, technology, and scholarship fuels sustainability and economic development.

Environmental and Natural Resources

Project Director

Meredith Weinstein

Organization

North Carolina State University

Accession Number

7000168

Programs to Conserve and Protect the Environment, Boost Sustainable Energy, and Mitigate Climate Change

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

North Carolina remains the 9th largest state in the nation with 10.6 million residents. In recent years, the state has gained more new residents than nearly all other states (after Texas, Florida, and Arizona). This population growth and associated sprawling development cause agricultural and recreational land loss, deforestation, loss of biodiversity, increased stormwater runoff, encroachment on riparian buffers, increased surface runoff, and an increase in pollutants compromising the quality of our water, soil and air. In addition, more people generate more waste. Litter accumulates in high-traffic areas, resulting in millions of dollars in annual government spending on roadside and community clean-up. The NC Department of Transportation reported $11 million in costs for roadway clean-ups in 2020 alone.

North Carolina's forests are facing increasing native and non-native threats, from invasive pests to a rapidly changing climate. As current landowners age and transfer property to the next generation, new landowners are struggling to sustainably maintain forested areas. NC also faces a growing threat from pesticide pollution. Farmers and homeowners find themselves with banned, outdated, or unwanted pesticides that are hazardous to landfills and waterways. Pesticide applicators must comply with changing environmental regulations to protect the environment, ensure worker safety, and avoid hefty fines.

Climate change, deforestation, air pollution, water pollution, loss of wildlife, and natural resource depletion threaten our ecosystems, increase rates of disease, decrease security (food, water, air), raise sea levels and temperatures, and cause severe weather events. To sustain the quality and diversity of North Carolina's natural resources, conserve and protect the environment, boost sustainable energy, and mitigate climate change, there is a need for research-based natural resource stewardship, and climate-smart agricultural and forestry best management practices to be developed, transferred to stakeholders and adopted.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Through efforts of NC State Extension to sustain the quality and diversity of North Carolina's natural resources by conserving and protecting the environment, boosting sustainable energy, and mitigating climate change:

- NC State Extension Specialists disseminated new environmental and natural resource information and best practices through the publication of 57 peer-reviewed **factsheets** to educate Extension Agents, forest owners, natural resource professionals, municipal officials, homeowners, engineers, municipal governments, and private contractors.

- NC State environment and natural resource Extension Specialists maintain 8 **web portals** containing 2,049 individual webpages to disseminate up-to-date research-based information and best practices. 13 new webpages were added in 2021 along with 49 new educational posts made to existing pages. The environment and natural resource websites maintained by Extension Specialists were viewed 208,071 times.

- NC State Extension Agents had a **digital media** reach of 257,567 and a **mass media** reach of 298,6361 in providing new environmental and natural resource educational information.

- 8,245 individuals attended **training** provided by Extension Agents, and an additional 14,134 individuals attended training provided by Extension Specialists on environmental and natural resource topics.

To protect North Carolina's forests, NC State Extension collaborated with 14 forestry programs through Southern Region Extension Forestry to develop the **Woodland Stewards webinar series**. The series provides Extension agents with a 4-week forestry program designed to educate new landowners. Since the series launched in 2019, it has reached a total of 542 participants from 44 states and Canada, impacting an estimated 79,000 acres of managed woodland.

Extension forestry held 2 **workshops** via Zoom, each featuring guest speakers and topics such as forest pest and disease identification and management, pine straw production, and the threat of rising sea levels to forest health. These events were widely promoted through social media and other agencies and NGOs. A total of 431 individuals participated, and an additional 31 viewed the workshops online. **As a result of NC State Extension forestry programs, new research-based forest conservation and climate-smart forestry information were transferred to stakeholders, empowering them to make better decisions to conserve and protect the environment.**

Under Extension's direction, the Center for Applied Aquatic Ecology (CAAE), in partnership with local government, maintains a network of **real-time remote monitoring systems** (RTRMs) in 3 major potable water supply reservoirs in partnership with local governments. The RTRMs provide high-frequency data 24/7 as an early warning system to help water treatment plants safeguard drinking water for about 750,000 NC residents. In 2021, the RTRMs collected more than 1 million key data points and posted data summaries to the CAAE's website, providing near real-time information to help water treatment plant operators optimize their filtration techniques cost-effectively. These data are also used by NC's environmental agency to improve the assessment and protection of these reservoirs. **As a result of NC State Extension's water monitoring programs, data on water quality was transferred to water treatment plants and other stakeholders, empowering them to make better decisions to ensure safe drinking water.**

In response to complaints of contamination due to the off-target movement of herbicides, Extension partnered with NC State researchers and the NC State Climate Office to develop a **Spray Conditions Tool** for the North Carolina Environment and Climate Observing Network (ECONet). This tool uses data from 17 of ECONet's research-grade weather stations across the state to provide key data to pesticide applicators so they can carefully time their applications and minimize pesticide drift. The tool provides user-friendly, color-coded information about spray conditions via desktop or mobile. Since the launch of this tool in 2020, it has been accessed over 3,510 times by over 1,000 unique users, and it has been incorporated into the NC Soybeans App to assist soybean producers. **As a result of NC State Extension's efforts, technology was developed to provide real-time information to help pesticide applicators make better decisions and reduce pollution caused by pesticide drift.**

Riparian buffers are key to protecting water resources in North Carolina. Many state and local rules protect the areas surrounding intermittent and perennial streams. These rules themselves can be confusing, and identification of water bodies subject to protection can be challenging to local municipalities, developers, engineering firms, and even state and local officials hired to enforce the rules. Even the background behind why the rules exist is often lost on those affected by these rules. Extension Specialists worked with the NC Department of Environmental Quality – Division of Water Resources to develop the 4-day Surface Water Identification and Training Certification workshop series. Since 2014, nearly 350 individuals have been trained during SWTIC workshops, including new regulators with DEQ, land developers/consulting engineers, and NC town officials with delegated authority to regulate the NC buffer rules. In 2021, Extension collaborated with DEQ to develop 3 half-day **workshops** for officials from NC towns on buffer rule background, updates, and examples of enforcement (60 participants). The combined training of regulators who enforce the buffer rules and the developers/engineers who navigate these rules has been extremely successful. Both entities that receive this training are not only more well versed in the background, rules, and practices to identify regulated water bodies, but also work together better. This will increase permitting efficiency and ultimately save agencies, towns, and developers time and money when dealing with development near buffers. **As a result of NC State Extension efforts, regulators and developers have increased their knowledge of riparian buffers so they can make more informed decisions and protect stream areas from pollutant runoff and erosion.**

Briefly describe how your target audience benefited from your project's activities.

In partnership with the New Hanover County Arboretum, Cooperative Extension undertook a multi-year effort to expand and add stormwater BMPs to reduce or eliminate stormwater runoff into the nearby Bradley Creek. Thanks to these efforts, runoff from the arboretum has been nearly eliminated, and the suite of BMPs provides a hands-on, outdoor classroom for students and professionals to learn about stormwater control on a commercial and residential scale. A stormwater walking tour was created for visitors to view the BMPs, and 8 lab sections were hosted with over 200 undergraduate students from the University of North Carolina Wilmington (UNCW)'s Environmental Sciences Department. In addition, the arboretum has hosted 30 grad students from UNCW's School of Public Policy, 25 participants in a statewide NC Soil and Water Conservation Conference, and 80 attendees from NC State's Department of Biological and Agricultural Engineering. **NC State Extension's trusted research-based technical assistance provided solutions to a stormwater runoff problem, and as the leader in experiential education, providing opportunities for students to put learning into practice.**

Cooperative Extension trained and certified 4,379 people in stormwater control measure inspection and maintenance. In 2021 Extension also supported the writing, production, filming, and promotion of 10 environmental educational videos and written materials to support the Town of Cary's urban water quality protection program. Cary plans to release these videos in 2022 and to share the information with other NC communities facing stormwater regulations. After attending Extension programs, 5,510 participants statewide implemented Extension-recommended practices to conserve water use and protect water quality. In addition, 9,414 participants increased their knowledge of best management practices for preserving natural resources, including practices associated with stormwater systems, septic system maintenance, erosion control, rain gardens, and forestry. **NC State Extension's leadership in experiential education equipped stormwater professionals to effectively transfer knowledge and skills into practice.**

To support compliance with pesticide regulations, Cooperative Extension in Hoke, Pasquotank, Camden, Chowan, Currituck, Gates, Perquimans, Rowan, and Cumberland Counties partnered with the NCDA to provide over 1,133 pesticide applicators with 1,386 hours of pesticide safety continuing education and re-certification credits via in-person and virtual classes. Extension in Wilkes, Surry, Stokes, Yadkin, and Forsyth Counties delivered an additional 8,400 credit hours of continuing education and re-certification credits to 400 growers and other pesticide license holders. Statewide, 10,151 people attended pesticide training, including 6,619 pesticide applicators who received 19,751 continuing education and re-certification credits.

Within domestic and peridomestic environments, a variety of habitats support the growth and development of arthropod communities (e.g., spiders, bed bugs, cockroaches, termites, ants, flies, mosquitoes, wasps, bees, beetles, fleas, lice, ticks, and silverfish). Unfortunately, competing stakeholder needs (consumer versus professional), public perception of "pests," concurrent management of beneficial arthropods, rapid evolution of insecticide resistance in urban pest populations, and the public health impacts of synthetic pesticide use make modern urban pest management exceptionally challenging. These issues have prompted the development of integrated pest management (IPM), a science-based strategy that uses multiple tactics (not just pesticide application) to manage pest populations until their presence falls below a predetermined threshold.

To improve pest management strategies in diverse pest systems, NC State Extension conducted applied research projects to develop control strategies relevant to stakeholders, and provided agent training, workshops, and fact sheets. The Plant Disease and Insect Clinic provided answers to stakeholder questions and direct consultation was provided to over 200 cases virtually, by phone, email, and on-site. This 1-1 attention to clients provided the education necessary to change stakeholder behavior, as less pesticide was applied after several consults. Continued efforts to educate stakeholders on the targeted, efficient use of pesticides will lead to improved pest management and reduced pesticide input statewide, improving the health and safety of humans and domestic pests in urban environments. NC State Extension extended research-based education on strategies for urban pest management to stakeholders through a variety of methods to promote the efficient use of pesticides. As a result, stakeholders applied fewer pesticides after consults. Further work in this area will lead to improved pest management and reduced pesticide input, improving human health and safety. **Transferring research-based pest management strategies is just one-way Extension is keeping our communities healthy and safe, protecting the environment, and reducing risk.**

To support sustainability practices, Extension Agents in Onslow and Jones Counties along with other local partners delivered a 5-week virtual education series covering topics such as recycling, composting, protecting pollinators and wildlife, rainwater harvesting, and minimizing food waste. This series reached 110 people from 4 states and 2 countries outside the US. Most participants reported gaining significant knowledge and a desire to implement these sustainable practices in their daily lives. Forty percent of respondents reported an increase in knowledge about reducing food waste, and 76% reported intent to use what they learned. Fifty-seven percent of respondents reported an increase in knowledge about composting, and 80% reported an intent to start composting. Fifty percent of respondents reported increased knowledge of recycling, and 100% reported intent to use what they learned. Respondents also reported improved knowledge of pollinators, with 85% reported an increase in knowledge about how to protect pollinators in their landscapes and 100% reporting an intention to use what they learned to protect pollinators. The majority of respondents also benefited from learning about rainwater harvesting, with 67% reporting an intent to implement new practices to conserve water quality in their landscapes. NC State Extension agents offered a variety of programs addressing issues related to environmental protection and sustainability. As a result of this programming, 10,876 participants demonstrated increased knowledge of natural resources and environmental issues, and 9,310 participants expressed a willingness to participate in conservation actions (such as rain gardens, wildlife management, conservation easements, land trusts, and generational planning). **NC State Extension's leadership in experiential education has helped program participants put learning into practice by implementing sustainable practices to conserve and protect the environment.**

Briefly describe how the broader public benefited from your project's activities.

Over the last 5 years, Extension has led over 11 streambank repair workshops in Western NC. Overall water quality improvements have been reported in 7 Madison County streams and 3 Buncombe County streams due to reduced concentrations of sediment, fertilizer contamination, and fecal bacteria. In addition, 2,530 feet of the stream were fenced off from livestock, 2,549 trees and other protective vegetation were planted by volunteers, 3,088 linear feet of the stream were stabilized through repairs and native plants, and 88,000 square feet of runoff was treated with stormwater BMPs to reduce erosion and petrochemical contamination.

Cooperative Extension led 6 streambank repair projects across the state in collaboration with local partners, engaging with 289 participants and repairing over 1,200 linear feet of streambank during the workshops. Local partners reported an additional 8,525 feet of streambank repaired after the workshops. Streambank repairs produce a long-term return on investment, for example, repairs installed in 2019 have reduced soil loss by 877 tons per year and facilitated the removal of

1,365 pounds of nitrogen and 1,338 pounds of phosphorus from streams annually. In addition, a survey of realtors and property appraisers estimated that properties with stable streams are valued at 10% higher than those with eroding streams, meaning that the properties where repairs were installed increased in value by an estimated $2,900,000. **NC State Extension's streambank repair efforts sustain the quality and diversity of North Carolina's natural resources by protecting drinking water, increasing property values, and protecting recreational spaces for all North Carolinians to enjoy.**

In Edgecombe County, the landfill has a storage area for pesticide containers that was almost at the overflow stage. To protect the environment from pesticide pollution, Cooperative Extension partnered with the Edgecombe County Solid Waste Department and a recycling company to conduct a pesticide container recycling program. As a result, 14,000 half-gallon containers and 2,500 1-gallon containers were collected, 100% of which were accepted for recycling. This event saved the community over $5,500 and saved room at the landfill. Extension in Johnston County processed 9,250 pounds of pesticide containers for recycling. In partnership with the North Carolina Department of Agriculture & Consumer Services (NCDA&CS), Extension in Franklin, Henderson, and Hoke Counties helped local farmers and homeowners dispose of 15,804 pounds of pesticide containers and unwanted pesticides, preventing a huge volume of pollution from entering the environment and saving an estimated $2.5 million in potential contamination clean-up costs. Cooperative Extension in Pitt County encouraged the recycling of pesticide containers through the maintenance of various collection sites, which allow growers to deposit triple-rinsed empty pesticide containers. By diverting these containers for reuse, 10,163 pounds of plastic were recycled, reducing agricultural producer disposal fees and extending the life of the landfill.

In addition to pesticide waste, farm operations generate large volumes of used oil each year. The Northampton County Cooperative Extension Office worked with producers to provide a cooperative program to reduce and control pollution in the soil and water. Two oil pick-ups yielded a total of 6,814 gallons of used oil collected in Northampton County in 2021. **NC State Extension's pesticide and motor oil recycling programs sustain the quality and diversity of North Carolina's natural resources by ensuring pollutants do not cause soil, groundwater, and surface water contamination.**

To reduce the environmental impact of littering, Extension in Carteret County launched the Big Sweep Initiative, scheduling monthly roadside clean-up events for March through December of 2021. Local businesses, civic organizations, military groups, and family groups provided 127 volunteers to remove over 5,000 pounds of litter and debris from roadways. In Pamlico County, Cooperative Extension worked with local partners to develop a litter awareness campaign that included developing materials to educate and encourage litter prevention and organized 2 community clean-up events, engaging 100 volunteers in collecting over 300 bags of roadside litter and removing approximately 3,000 pounds of litter from roadways. Extension in Pamlico County has laid a foundation for re-occurring litter awareness campaigns and plans to host annual roadside clean-up events in the future.

In Alexander County, Cooperative Extension launched a specialized clean-up for hazardous household items, partnering with local government and the NCDA&CS to collect and safely dispose of 6,986 pounds of paint-related materials and 14,884 pounds of latex paint in cans. Cleaning products, aerosols, mercury, and various other hazardous materials were also collected, securing a total of $16,860 in savings for citizens. **NC State Extension's litter and household hazardous materials recycling programs sustain the quality and diversity of North Carolina's natural resources by reducing litter in our public spaces and helping to improve aesthetic value, reducing pollution of waterways and environmental impacts on our local communities, and preventing harm to wildlife.**

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

The following professional development workshops were provided by Extension Specialists for Extension Agents in 2021 to facilitate the use and transfer of new research-based knowledge:

- Agricultural & Environment Law and Transportation: Overview & Opportunity
- Carbon Markets, Conservation Practices, and Ag Labor
- NC State Climate Office: Tools, Resources & Climate Communication

- It's Getting Hot Out There: Urban Tree Species & Climate Change
- The Educational Needs of North Carolina's Forest Landowners
- A Walk in the Woods: Visualizing Benefits of Forest Management
- Streambank Repair Certification Workshop
- Forest Farming Woodland Botanicals (ginseng, goldenseal, etc.)
- Invasive Forest Pests: "Poolside Pests" Outreach & Hands-On ID
- Wood Products Going Stale? Not in North Carolina

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

Climate change, deforestation, air pollution, water pollution, loss of wildlife, and natural resource depletion threaten our ecosystems, increase rates of disease, decrease security (food, water, air), raise sea levels and temperatures, and cause severe weather events. NC State Extension led efforts to sustain the quality and diversity of North Carolina's natural resources by conserving and protecting the environment, boosting sustainable energy, and mitigating climate change. As a result of Extension's efforts, a tool was created that minimizes off-target movement of herbicides. Extension also increased the safe application of pesticides and use of alternate control measures through pesticide safety training and IPM workshops. NC State Extension improved water quality through workshops on the protection of riparian buffers, workshops and implementation of stormwater BMP projects, and streambank repair efforts. Extension educated local communities about composting and recycling, hosted pesticide container and used oil recycling events, and litter clean-up days and successfully reduced their negative impact on the community and environment. NC State Extension provided the means for North Carolina's natural resources and environmental quality to be protected, conserved and enhanced, and ecosystem benefits optimized.

Natural Resource and Environmental Systems

Project Director

Lauren Hargrave

Organization

North Carolina Agricultural and Technical State University

Accession Number

7001859

Farm Best Practices

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Current trends show that small-scale and limited resource farms provide critical and essential family economic assets to North Carolina and the southern United States. These farmers and landowners (having landholdings of 20 acres or less) generally do not realize the full benefit of their lands nor do they understand how efficiently they can protect and manage their agriculture and natural resources, such as soil, water, and air quality. As a result, they cannot compete with large-scale farms and woodland owners. Protecting a farm's soil, water, and environment as climate change occurs is immensely important, as are sound agricultural management practices. Providing the knowledge and skills to manage soil, water, agricultural, and forestland resources will reduce environmental footprints.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

The Agriculture and Natural Resources (ANR) specialist distributed natural resource testing kits to ANR Extension agents and technicians. A farm sample has been collected from the demonstration plot to develop a baseline for the Alley-Cover Cropping project at the University Farm. The data is currently being analyzed. In fall 2021, Cooperative Extension at N.C. A&T hosted 100 participants in the Grassroots Leadership Conference, where discussion focused on forest management resources, conservation practices, and land ownership issues. The ANR specialist also distributed the guide *Profitable Farms and Woodland: A Practical Guide in Agroforestry for Landowners, Farmers and Ranchers*, published by the previous program director of the Renewable Resources Extension Act.

Case studies were developed that addressed climate resiliency on small farms. Extension at N.C. A&T has conducted educational programs and developed demonstrations in high tunnel agriculture, cover crops, and conservation practices at our University Farming, and has made that work accessible to small-scale farmers and landowners.

Briefly describe how your target audience benefited from your project's activities.

Three growers from different parts of the state were interviewed to understand the themes and practices that are increasing their overall sustainability during a time of changing climate. Based on the interviews, N.C. A&T felt a critical need to perform more research and Extension education on climate-smart agricultural practices. Participants mentioned the need for more information and educational workshops on climate-smart agricultural practices to improve soil health, and for information on how to increase food and nutritional security at the local scale under a climate change scenario. As a result, we connected with North Carolina State Climate Office to N.C. A&T collaborate on teaching, training, and educating small-scale, limited resource, and minority farmers on climate change and how to modify farming practices under a climate change scenario.

Sixteen kit bags were prepared, including a measuring kit for soil pH, EC, irrigation, auger, clippers, GIS, video kit, temperature, conductivity, digital microscopes, and comprehensive soil testing kits. These help ANR Extension agents and technicians diagnose any rapid issues a farmer or landowner has with their soil, water, farm, or land environment.

The Profitable Farms and Woodland manual helped our farmers and landowners learn about the possibilities, challenges, and opportunities they have with their small farms and woodlands. So far,15 guidebooks have been distributed to farmers or farmer groups and to county Extension agents across 14 counties who needed, requested, or showed interest in the manuals during meetings or personal phone calls.

Briefly describe how the broader public benefited from your project's activities.

N/A

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

N.C. A&T plans to distribute more natural resource testing kits during Small Farms Week (March 20-26, 2022) and afterwards through meetings, workshops, and visits with our contacts in various counties. We plan to distribute them to the 14 counties where our ANR agents and technicians who serve small-scale farmers in North Carolina are located.

N.C. A&T is also working on providing more training and educational forums in 2022 on sustainable soil health and sustainable and resilient agriculture for small-scale farmers.

Onsite Wastewater Treatment Systems: Assessing the Impact of Soil Variability and Climate Change

Project Director

Matthew Ricker

Organization

North Carolina State University

Accession Number

1024229

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Millions of people live in coastal regions of the eastern United States, and many of them rely on septic (on-site) systems to effectively treat wastewater and protect water quality. The functionality of on-site systems can be adversely affected by predicted coastal climate change via increased flooding, salinization of soils, and rising ground water tables. To date, little is known about the impacts of these climate variables on soils and septic systems in North Carolina.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Coastal climate change is predicted to cause increased flooding, salinization of soils, and rising ground water tables. These factors will likely negatively affect the ability of existing septic systems to treat waste and protect water quality. We analyzed geospatial data from 7 coastal counties (Bertie, Brunswick, Camden, Chowan, Currituck, Pasquotank, Perquimans) in North Carolina to understand septic system vulnerability to sea level rise. Our preliminary research has located 30,361 coastal systems that are within 500 m of the coastline and likely at risk because of sea level rise over the next century. Of these located systems, 328 are located within minimum required setback distances from coastal shorelines (50 feet) and most vulnerable to sea level rise.

Using soil survey data in GIS, we have mapped soil series and joined the data to the location of existing septic systems. We have found that 47% of existing permitted systems are located in soils that have seasonal high water tables within 100 cm of the soil surface. These systems are at most risk for shrinking vertical drainfield separation distances as groundwater tables in the coastal zone rise with sea level. The majority of coastal septic systems in our study counties are installed in mineral soils classified as Ultisols (61%) or Entisols (32%).

Only 2.8% of existing systems were in problematic areas mapped as Histosols or “unknown” soil type. We have also acquired geospatial NOAA sea level rise projections through 2050 and 2100. Use of sea level rise projections and existing location of permitted septic systems showed that by 2100, with 3 feet of relative sea level rise, there would be 137 septic systems inundated or submerged. Geospatial products from our study can be used by land managers to predict problematic landscapes for future installation of on-site wastewater treatment systems or areas where failure of previously installed systems is more likely to occur.

Briefly describe how your target audience benefited from your project's activities.

Our research data is being used in extension activities in coastal communities to inform the public about coastal septic systems, water quality, and human health. Digitized site-specific paper soil maps have been compiled and will become available for the entire outer banks region of North Carolina in 2022. These maps have greater detail than those publicly available through the Natural Resources Conservation Service Web Soil Survey and would be useful for land use planning in the region.

Briefly describe how the broader public benefited from your project's activities.

The locations of problematic septic systems are available relative to sea level projections for advanced planning in the 7 coastal counties we are working with in North Carolina. Our project has also provided in advanced training of 2 graduate students and 1 undergraduate student.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

In 2022 we plan to start field studies of specific septic system soils and production of green house gases in response to flooding and salinization.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

Millions of people live in coastal regions of the eastern US. Coastal climate change is predicted to cause increased flooding, salinization of soils, and rising ground water tables. These factors will likely negatively affect the ability of existing septic systems to treat waste and protect water quality. NC State researchers analyzed geospatial data from 7 coastal counties to evaluate septic system vulnerabilities. Preliminary research has located 30,361 coastal systems that are within 500 m of the coastline and likely at risk because of sea level rise over the next century. This data can be used by land managers to predict problematic landscapes for future installation of on-site systems and target areas where failure of previously installed systems is likely to occur. In coastal communities this data is being used in extension activities to inform the public about coastal septic systems, water quality, and human health. Digitized site-specific paper soil maps have been compiled and will be available for the entire Outer Banks region of NC in 2022 to support the economic, social, and environmental welfare of North Carolinians. This is just one example of how NC State research is preserving natural resources and proactively addressing future impacts from climate change.

Synthesis of Advanced Carbon Nanomaterials from Biomass for Contaminants Removal and Energy Storage

Project Director
Abolghasem Shahbazi
Organization
North Carolina Agricultural and Technical State University
Accession Number
1023319

Synthesis of Advanced Carbon Nanomaterials from Biomass for Contaminants Removal and Energy Storage

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

The project addresses multiple important issues related to Protecting Environmental and Natural Resources Systems. The research focused on process development for biochar made from various biomass materials and the use of biochar in advanced biomaterials form to address needs for biofuels, energy storage, protection from penetrating radiation, and contaminant removal from wastewater.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

The goal of the project is to perform research on thermochemical conversion technology (pyrolysis and Hydrothermal carbonization) to convert a range of potential wastes and inexpensive carbonaceous materials into advanced multifunctional carbon nanomaterials with high performance in many important applications, including energy storage (e.g., supercapacitor, battery), and environmental protection (e.g., wastewater treatment and radiation protection).

The major activities and achievements during the reporting period are summarized as follows:

1. Swine manure, oak wood and miscanthus were collected from N.C. A&T State University Farm. Biochars were produced via thermochemical conversion technology including hydrothermal carbonization and pyrolysis under different temperatures and production conditions. Then, the obtained biochars were characterized and studied for phosphate adsorption from wastewater.

2. Developed a method for increasing the electrochemical performance of a stand-alone carbon nanofibrous electrode material (electrospun carbon nanofiber with chlorella doping) for use in supercapacitors. The activated chlorella-derived carbon nanofibrous electrode materials displayed good electrochemical performance for supercapacitor application when combined with chemical activation (KOH). The activated carbon nanofibrous electrode material from electrospinning polyacrylonitrile (PAN)/chlorella had shown a specific capacitance of 182 F/g at a current density of 0.5 Ag-1, which is nearly 6 times greater than the corresponding electrospinning electrodes without chlorella.

3. Biochar incorporated electrospun nanofiber aerogel synthesis for electrode applications. Biochar integrated and fluorine-doped biochar incorporated aerogel supercapacitor electrodes were successfully made and described to evaluate the performance of electrode materials. The specific capacitance of biochar incorporated aerogel samples

was higher (187F/g for fluorine doped biochar integrated nanofibrous aerogel). As a result, fluorine with biochar integrated electrospun naofibrous aerogel structures performed best electrochemically.

4. For the evaluation of phosphate sorption, activated biochars were impregnated with iron Fe2O3 and studied for phosphate adsorption. Magnetic biochars showed higher adsorption capacity due to the magnetite iron formation on biochars. The results suggest that activation and iron treatment of biochar increased surface area and enhanced porous structure and added acidic functional groups contributed to the increased nutrient sorption capacity.

Briefly describe how your target audience benefited from your project's activities.

The target audience that was served by this project include but not limited to the following: Environmental Remediation agencies or organizations who are looking for a bio-based treatment options for remediating water contaminated with heavy metals and chemicals; Government Agencies and Business who are seeking technically and economically feasible strategies to mitigate climate change by removing CO2 from the carbon cycle; Agricultural, Biofuel and Chemical Industry who are interested in the bio-energy production, energy storage, catalysis, environmental protection and other biochar-based materials production for industrial purposes; Small farmers who are interested in growing miscanthus grass on their marginal lands to improve farm revenue; Graduate students who are interested in the area of biotechnology, bioenergy, biobased products and waste management. This project demonstrated to the above audience how to develop a sustainable system to treat waste biomass, recover energy, mitigate CO2 emission, and produce biochar-based functional materials for various new state of the art applications.

Briefly describe how the broader public benefited from your project's activities.

Introduction of a well-understood process developed by this project into the rural area would improve economics of swine farming by reducing waste treatment costs and generating additional revenues from biochar. Utilization of the carbonaceous materials developed from this project would provide new business opportunities for various industries/stakeholders (e.g., batteries manufacturers, biotechnology, and material research companies). These products can, in turn, enable the cost-effective production of advanced biofuels, improve energy security, reduce greenhouse gas emissions, and contribute to U.S. job growth.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

The project provided training opportunities to graduate and undergraduate students who are interested in employment opportunities in the bio-based industry. The project also provided hands-on learning opportunities for the undergraduate and graduate students in Biological Engineering program, Energy and Environmental Science, and Nanoscience and Nanoengineering. The students can conduct research for their dissertation, thesis, and senior design by participating in the project. We also provided training workshop on biochar production and waste water treatment for high school students who participated in the Research Apprenticeship Program in the College of Agriculture.

Publications:

Sutton, Khiry, Xiu, S., Shahbazi, A. Development of fluorine-intercalated biochar material for radiation shielding. Journal of Analytic and Applied Pyrolysis, 2021, 155:105038

Asare, K., Hasan, M. F., Shahbazi, A., Zhang, L. (2021) A comparative study of porous and hollow carbon nanofibrous structures from electrospinning for supercapacitor electrode material development. Surface and Interfaces. 26, 101386.

Hasan, Md Faruque; Mantripragada, Shobha; Gbewonyo, Spero; Xiu, Shuangning; Shahbazi, Abolghasem; Zhang, Lifeng. Carbon Nanofibrous Electrode Material from Electrospinning of Chlorella (Microalgae) with Polyacrylonitrile for Practical High-Performance Supercapacitor. International Journal of energy research (under review)

Emerging and Legacy Contaminants in Aquatic Ecosystems: Examining their Transport, Fate, and Biological Effects

Project Director

William Cope

Organization
North Carolina State University
Accession Number
1020239

"Forever Chemicals" Measured in North Carolina's Aquatic Food Web

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Per- and polyfluoroalkyl substances (PFAS) compounds, including GenX have been in detected in water, food, soil, and air throughout world, including in North Carolina. PFAS compounds are human-made chemicals that were engineered to resist friction and heat, and are in many products that we use daily, from furniture to food packaging. However, it is their "non-stick" and anti-stain" characteristics that make them persist in the environment (hence "forever chemicals" and pose a risk to our health.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

A study measuring real-time PFAS contamination levels along the entire food chain of a major Atlantic coastal river was conducted. The research team collected water, sediment, algae, plant, insect, fish, crayfish, and mollusk samples at five study sites along the length of the Yadkin-Pee Dee River, which begins in Blowing Rock, NC, and runs 230 miles to empty into the Atlantic Ocean at Winyah Bay, South Carolina. Samples were analyzed for 14 different PFAS compounds.

Briefly describe how your target audience benefited from your project's activities.

PFAS compounds were found in every step of the Yadkin-Pee Dee River food chain, even though the river does not have a known industrial input of these compounds. The study identifies strong links between ecosystem groups that lead to the buildup of PFAS compound concentrations in animals and humans that sit higher on the food chain. See https://cals.ncsu.edu/applied-ecology/news/pfas-in-yadkin-pee-dee-river-food-chain/ for more information.

Briefly describe how the broader public benefited from your project's activities.

Our findings will directly inform natural resource management and human health concerns by state and federal agencies and will lead to greater understanding of the consequences of exposure to forever chemicals.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

The environment and human health are threatened by "forever chemicals," human-made chemicals found in products engineered to resist friction and heat that persist in the environment indefinitely. NC State researchers conducted a study measuring contamination levels for 14 key forever chemicals along the entire food chain of the Yadkin-Pee Dee River, a major Atlantic coastal river. These chemicals were found in every step of the food chain despite the fact that the river does not have a known industrial input of these compounds. This study identifies strong links between ecosystem groups that lead to the buildup of these compounds in animals and humans that sit higher on the food chain. These findings will directly inform natural resource management and human health-related policymaking at the state and federal levels, leading to a greater understanding of the consequences of exposure to forever chemicals. Through this and similar efforts to address systemic environmental threats, NC State is strengthening communities and serving all North Carolinians.

Closing Out (end date 09/07/2023)

Poultry Litter Management in North Carolina

Project Director
Stephanie Kulesza
Organization
North Carolina State University
Accession Number

1019095

Impact of poultry litter application on soybean yields and quality

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Growers in NC want to know whether application of poultry litter improves yields and impacts quality.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Our work showed that soybean does not benefit from application of nitrogen at the beginning of the season, whether in the form of inorganic nitrogen or poultry litter. However, the application of poultry litter did not negatively impact soybean, indicating application to meet the phosphorus and potassium requirements is adequate.

Briefly describe how your target audience benefited from your project's activities.

Growers benefited from this research through attendance at grower meetings and other extension events. Growers can now be confident in their litter application decisions and reduce litter application to meet phosphorus and potassium requirements, instead of worrying about potential negative impacts to soybean yield and quality.

Briefly describe how the broader public benefited from your project's activities.

The public benefits from the reduction in potential environmental impacts as a result of over application of litter on soybean crops. Additionally, the greater grower community can now utilize poultry litter in crops that will utilize the nitrogen, now that we know the soybean does not benefit from the nitrogen in these products.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

Agronomic crop growers were interested in knowing whether application of poultry litter improves crop yields and quality. NC State researchers found that soybean crops do not benefit from the application of nitrogen in the form of poultry litter or inorganic sources at the beginning of the season. However, the application of poultry litter did not negatively impact soybean crops, indicating that litter can be applied to meet other nutrient requirements (phosphorus and potassium). This information was provided to growers through grower meetings and other Extension events, enabling growers to be more confident in their litter application decisions and tailor those decisions to meet phosphorus and potassium requirements. Through this integrated research and extension project, NC State is translating research-based knowledge into everyday solutions to grow the future of NC agriculture.

Closing Out (end date 09/07/2023)

Understanding and managing ecological effects of urbanization from organismal to landscape scales

Project Director

Elsa Youngsteadt

Organization

North Carolina State University

Accession Number

1018689

Results for project period 10/1/2020 - 9/30/2021

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Primary goals were to understand how warming affects the physiology and abundance of insects, and how these effects vary geographically as a function of regional background climate. These problems are relevant in urban landscapes-- where the urban heat island effect alters local climates--and in non-urban landscapes experiencing global warming.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

During the project period, we obtained the following research results which, together, contribute to the goal of understanding effects of warming on insect ecology:

(1) Behavioral thermoregulation is unlikely to protect insects from a warming climate. That is, as a habitat gets warmer, so do the insects that live in it. Our data show that ants do not use different microhabitats or times of day to avoid temperatures outside their preference range. (Data analysis for this project was conducted during the project period and it is in prep for publication.)

(2) Bubmle bees carrying larger amounts of pollen reach hotter body temperatures, approaching the danger zone of lethal temperatures on hot days. This effect corroborates other studies that demonstrate widespread population declines and poleward range contractions in bumble bees. In warmer climates, bumble bees may have to forage at dangerous temperatures, or carry smaller amounts of food back to their colonies. (This work was completed during the project period and is in prep for publication.)

(3) Bee populations are often monitored with sampling techniques that have not been validated. For the first time, we compared common bee sampling methods to mark-recapture population estimates and found that active netting provides a quantitative index of the underlying community, whereas pan traps (aka bee bowls) do not. This is relevant to project goals because assessing the effects of environmental change on insect populations requires a good way to actually measure those populations. (This work was submitted for publication during the project period and published in March 2022.)

(4) With collaborators, my team collected data on bee health and pollination services across urbanization gradients in Raleigh, Atlanta, Detroit, Phoenix, and Denver. Sample processing is ongoing.

Briefly describe how your target audience benefited from your project's activities.

This research program aims to benefit the broader public (see below) as well as scientific audiences including ecologists, entomologists, and global change biologists, conservation biologists, and conservation practitioners. To benefit this community by sharing ideas and new results, we presented this research at the Entomological Society of America (southeastern branch meeting), Association of Southeastern Biologists, the Natural Areas Conference, and Clemson University.

Our 2020 Environmental Entomology paper won that journal's Peoples' Choice award for most read and shared papers.

Briefly describe how the broader public benefited from your project's activities.

The broader public is one of my target audiences, and benefited from synergistic extension and outreach activities that my team conducts to share information about bee diversity and provide practical guidance on supporting polinators in urban areas.

Bee hotels were one focus area for extension and outreach during the project period. Bee hotels are like bird houses for solitary bees. They have become popular installations at public gardens, museums, and backyards. However, available plans and pre-made structures are often poorly designed or come with no maintenance information, potentially turning them into death traps rather than habitat enhancements. To help disseminate best practises, we held a bee hotel build-along event on Feb 27, 2021. During the event,100+ participants listened to a brief lecture about bee hotel design and maintenance, then constructed their own bee hotels following a real-time demonstration by experts at the NCSU Maker Center. In advance of the workshop, we prepared 42 kits for participants to purchase and assemble during the event; these sold out in one day. We shipped kits to participants in four states. Nine months after the event, we surveyed participants and received 14 responses; 86% reported that they had installed their hotel outside, and of those, 52% were occupied by bees in the first year.

We also fielded seven direct inquiries from stakeholders about bee hotel design and maintenance, and prepared a peer-reviewed extension document to reinforce these activities (in press for 2022).

These and continued efforts are resulting in more and better-maintained nesting resources in the landscape for solitary bees. Prior research indicates that nesting resources can limit bee populations, and thus—in the long term—improved nesting opportunities may help reduce pollinator declines.

My team also provided six additional extension/outreach presentations on the topic of wild bee diversity and conservation with a combined audience of ~800 people.

Our identification guide to bees of North Carolina was accessed 12,842 times in 2021. https://content.ces.ncsu.edu/the-bees-of-north-carolina-identification-guide

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

No major changes.
Problems: The usual pandemic problems--we are working to recover from setbacks due to travel restrictions and delays.
Training and professional development: During the report period my lab comprised three graduate students, two research associates and five undergraduates who gained training and experience in research techniques and scientific communication; the senior personnel also gained experience mentoring student assitants. I sit on seven additional graduate student advisory committees.

How results have been disseminated--scientific presentations

Youngsteadt, E., and C. Sorenson. 2021. The impact of prescribed burning on native bee communities (Hymenoptera: Apoidea: Anthophila) in longleaf pine savannas in the North Carolina sandhills. **2021 Natural Areas Conference**: Life From the Ashes: Exploring the Impact of Prescribed & Natural Fire on Insects and Other Invertebrates (virtual).

The future of insects in a warming, urbanizing world. 2021. **Clemson University**, Entomology seminar series, Clemson, SC (virtual).

Briggs, E.*, and E. Youngsteadt. 2021. Counting bees: A comparison of survey methods for estimating wild bee abundance. **Association of Southeastern Biologists**, 82nd Annual Meeting (virtual). Poster.

Targaszewski, M.*, E. Youngsteadt, and C. Sorenson. 2021. Effects of artificial pollination on reproduction in female populations of *Rhus michauxii* Sarg. **Entomological Society of America**, **Southeastern Branch Meeting** (virtual). Poster.

Ruzi, S. A., E. Youngsteadt, J. A. Kettenbach, A. L. Hamblin, and R. E. Irwin. 2020. Urbanization shapes bee (Apoidea) biodiversity through time. **Entomological Society of America**, virtual annual meeting.

How results have been disseminated--scientific publications

Meineke, E. K.†, E. Youngsteadt†, M. K. Lippey, and K. C. R. Baldock. In press. Terrestrial Invertebrates. Chapter in: C. Nilon and M. Aronson, eds. *Routledge Handbook of Urban Biodiversity*, Routledge.

Youngsteadt, E., and A. J. Terando. 2020. Ecology of urban climates: The need for landscape biophysics in cities. Chapter 8 in: P. Barbosa, ed. *Urban Ecology: Its Nature and Challenges*. CABI.

Moylett, H., E. Youngsteadt, and C. Sorenson. 2020. The impact of prescribed burning on native bee communities (Hymenoptera: Apoidea: Anthophila) in longleaf pine savannas in the North Carolina sandhills. ***Environmental Entomology*** 49:211–219 https://doi.org/10.1093/ee/nvz156

How results have been disseminated--public presentations

Sept 2021. Get to know your carpenter bees. **NC Museum of Natural Sciences BugFest** (Virtual attendance 25; 87+ Youtube views)

July 2021. Urban bees: Biology, diverstiy, and health. **Denver Urban Garden Network**

April 2021. Bees and fire: Do they mix? **NC Pollinator Conservation Alliance** webinar series (Virtual attendance: 70)

Mar 2021. Getting to know the wild bees. **Concord Wildlife Alliance & NC Wildlife Federation**, virtual meeting (Attendance 96)

Feb 2021. **Bee hotel build along** (Virtual workshop, attendance 100, kits sold out with 42 distributed)

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

To address emerging challenges associated with climate warming in urban and non-urban landscapes and protect local pollinators, NC State researchers conducted a groundbreaking comparison of bee sampling methods used to capture data about bee populations and identified an approach that accurately quantifies populations. In addition, NC State held a bee hotel building event and workshop to teach over 100 participants how to create and maintain good habitats for bees. Researchers also fielded inquiries from stakeholders about bee hotel design and maintenance and prepared a peer-reviewed Extension document to support these activities (planned for release in 2022). In addition, 800 stakeholders were reached via 6 Extension and outreach presentations on the topic of wild bee diversity and conservation. In addition, NC State's identification guide for NC bees was accessed 12,842 times in 2021, and research results were delivered in 5 scientific presentations, 3 scientific publications, and 5 public presentations. This demonstrates how NC State's research faculty constantly partners with NC State Extension to deliver research-based knowledge to all North Carolinians, helping them transform science into everyday solutions that grow our future.

Closing Out (end date 09/07/2023)

Quantification of Land Use Effects on Soil Ecosystem Services in Depositional Landscapes

Project Director

Matthew Ricker

Organization

North Carolina State University

Accession Number

1017729

Enhanced Knowledge of Floodplain Soils to Improve Land Use and Conservation Planning

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Floodplain soils can provide beneficial ecosystem services by removing nutrients from surface waters if managed correctly. Currently in the Southeast United States there is great uncertainty as to how much carbon and phosphorus riparian zones contain. We are using a soil survey approach to quantify nutrient storage and improve floodplain maps to identify priority areas for management and conservation.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

For this research we identified and sampled 110 sites across North Carolina. This effort represents the most comprehensive evaluation of floodplain soils in the state and included forested, agricultural, and urban areas. Our research showed that phosphorus was not saturated in any of the soils we evaluated, indicating these floodplains remain an important sink for phosphorus in floodwaters. Carbon storage was variable and related to preserved topsoil at depth indicating that deep carbon burial is important for atmospheric carbon dioxide sequestration in floodplain. We found that only urban land use was predictive of elevated phosphorus and decreased carbon content in floodplain soils. Our findings suggest urbanization may decrease the ecosystem services provided by forested floodplains of the southeastern United States.

We also have begun to separate "hot spots" of carbon storage on publicly available soil map products like Soil Survey Geographic Database (SSURGO). One method of importance for land managers is the use of the National Wetland Inventory (NWI) data to identify wetlands with more accuracy along floodplain corridors. Wetlands store significantly more carbon compared to non-wetlands and therefore should be conserved and managed to maintain natural ecosystem services. Our research methods in North Carolina has decreased the uncertainty of wetland locations in broadly mapped floodplains from 45% to 20%. Our methods can be employed in the state to better distinguish between floodplain soils and probable wetlands for advanced land use planning and conservation plans.

Briefly describe how your target audience benefited from your project's activities.

Our research has established baseline data for floodplain soils across the Piedmont region of North Carolina. Numerous land managers have inquired about this research for applications in geoscience, forestry, and infrastructure construction planning in North Carolina. One graduate student completed her M.S. degree with this research and all data related to carbon,

phosphorus, and floodplain wetland separation are available at: https://repository.lib.ncsu.edu/handle/1840.20/39406

Briefly describe how the broader public benefited from your project's activities.

Broadly we have quantified ecosystem services for floodplains in the southeastern United States that can be compared to other regions globally. In addition, our research has trained multiple students who are now working in the soil science field and are more aware of the importance of floodplains in land use planning decisions. Eventually, our methods could be used to update broad floodplain soil map units in the Natural Resources Conservation Service (NRCS) Soil Survey Geographic Database and become available to all public users in the United States via Web Soil Survey (https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm).

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

NC State researchers are using a soil survey approach to quantify nutrient storage and improve floodplain maps to identify priority areas for management and conservation, reducing the uncertainty surrounding the nutrient (carbon and phosphorus) concentrations in the vegetated riparian zones next to natural water sources. Researchers identified and sampled 110 forested, agricultural, and urban sites across NC, an effort that represents the most comprehensive evaluation of floodplain soils in the state. The findings suggest that urbanization may limit the ecosystem resources provided by the forested floodplains of the Southeastern US. NC State researchers have also reduced the uncertainty of wetland locations in broadly mapped floodplains from 45% to 20%, and these methods can be employed statewide to enhance land use and conservation planning. Numerous NC land managers have inquired about this research for applications in geoscience, forestry, and infrastructure construction planning. This effort exemplifies how our world-leading faculty and exceptional field faculty are providing high-tech, high-touch expertise to safeguard the environment and serve the unique needs of diverse clients.

Closing Out (end date 09/07/2023)

Evaluation of Ecosystem Services and Performance Criteria in Restored Wetlands

Project Director
Michael Vepraskas
Organization
North Carolina State University
Accession Number
1017134

Results for Project Period 10/1/2020 - 9/30/2021

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Wetlands that have been drained and used for agriculture can be restored, but the process is expensive. Methods to assess the quality and success of restored wetlands are lacking. This project is developing ways to assess the success of restored wetlands that are fast, economical, and scientifically based.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Restoring a drained wetland used for growing agricultural crops requires that the original hydrology and vegetation be re-established such that the soils can again accumulate carbon. We first improved the methods for evaluating wetland hydrology on-site by correlating the number of “wetness” indicators to specific periods of waterlogging. Plant characteristics were also identified, such as tree height, that were correlated with soil organic carbon increases. Statistical models were then developed--based on key hydrology, plant, and soil characteristics--for 11 wetlands of different ages that had been successfully restored. These relationships would enable field personnel to assess whether a restored site was within the ranges expected for a successfully restored wetland.

Briefly describe how your target audience benefited from your project's activities.

Wetland regulators will have new tools to use for evaluating restored wetlands.

Briefly describe how the broader public benefited from your project's activities.

Successfully restored wetlands improve water quality, mitigate flooding, and provide wildlife habitat which are valuable ecosystem services. Wetlands that not been adequately restored do not provide these services and functions.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

Wetlands that have been drained and used for agriculture can be restored to support environmental health, but the process is expensive. To address this challenge, NC State researchers have developed statistical models to assess wetland restoration. Thanks to this effort, wetland regulators have new tools to evaluate and enhance wetland restoration in order to improve water quality, mitigate flooding, and provide wildlife habitats that play valuable roles in ecosystem preservation. Through this project, NC State is transforming science into practical solutions that enhance environmental resilience and serve all North Carolinians.

Closing Out (end date 09/07/2023)

Measuring Soil Physical Property Dynamics

Project Director

Josh Heitman

Organization

North Carolina State University

Accession Number

1017009

Measuring soil physical property dynamics

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Soil processes for agricultural, engineered, and natural systems are greatly affected by the dynamic soil physical arrangement (i.e., structure and density). Our research is developing approaches for monitoring dynamic changes to soil density and to developing better practices for compost utilization to improve soil properties of degraded soils.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

We developed a framework for bulk density-associated pedo-transfer functions (PTFs) to describe soil water retention curves (SWRCs). The newly developed PTFs provided reliable WRC estimates for the validation datasets, with mean RMSE values of 0.055 and 0.059 cm3 cm-3, respectively. The accuracy of the new PTFs was comparable to or better than other PTFs. The new PTFs have the potential to be integrated into crop and soil management models to represent bulk density impacts on WRCs under field conditions.

Based on an extended de Vries model, a thermo-TDR sensor estimated soil bulk density (ρb) values well. Ignoring root contributions to bulk soil heat capacity introduced 7%, 14% and 14% errors in thermo-TDR estimated ρb values for loamy sand, sandy loam, and clay loam soils, respectively. A critical root density of 0.04 g cm3 was determined beyond which roots may induce ρb errors greater than 0.1 g cm3 with the thermo-TDR technique.

We also determined the efficacy of compost as a soil improvement measure to reduce runoff volume, improve runoff quality, and increase vegetation establishment on a disturbed sandy clay subsoil representing post-development conditions. Results of our study suggest (1) tilling is a viable option to achieve high infiltration rates and reduce runoff volumes, (2) compost incorporation does not reduce nor improve water quality, and (3) compost may yield more robust vegetation establishment.

Briefly describe how your target audience benefited from your project's activities.

Our primary target audience is the research community. Our work was shared through 14 refereed research publications and through presentations at scientific meetings.

Briefly describe how the broader public benefited from your project's activities.

Soil resources are critical for agriculture, human infrastructure, and environmental quality. Our work provides a basis to monitor and manage soil resources, particularly in degraded soil environments. This function is important to society as a whole.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Peer-Reviewed Journal Articles

Crozier, C., H.D.R. Carvalho, A. Johnson, M. Chinn, and J.L. Heitman. 2021. Appropriate “Marginal” Farmlands for Second-Generation Biofuel Crops in North Carolina. Ag. Env. Letters 6:e20041.

Dick, D.L., T.G. Gardner, J.P. Frene, J.L. Heitman, E.B. Sucre, and Z. Leggett. 2022. Forest Floor Manipulation Effects on the Relationship Between Aggregate Stability and Ectomycorrhizal Fungi. For. Ecol. Manage. 505:119873

Ile, O., M. Aguilos, S. Murkoc, J.L. Heitman, and J. King. 2021. Root Biomass Distribution and Soil Physical Properties of Short-Rotation Coppice American Sycamore (Platanus occidentalis L.) Grown at Different Planting Densities. Forests. 12:1806

Rivers, E., J.L. Heitman, R.A. McLaughlin, and A. Howard. 2021. Reducing Roadside Runoff: Tillage and Compost Improve Stormwater Mitigation in Urban Soils. J. Environ. Manag. 280:111732.

Stephenson, T.D., H.D.R. Carvalho, M.S. Castillo, C.R. Crozier, T.J. Smyth, and J.L. Heitman. Water Use and Biomass Yield of Bioenergy Crops in the North Carolina Piedmont. Agronomy J. 2021:1-11.

Extension Articles

Kranz, C.N., Heitman, J.L., McLaughlin, R.A. 2022. Incorporated Compost Effects on Infiltration, Water Quality, and Vegetation Establishment. IECA Environmental Connections Magazine. Jan/Feb Issue. Accepted.

Presentations and Abstracts

Carvalho, H.D.R., J.L. Heitman, A.M. Howard, A. Johnson, C. Crozier, M. Chinn, T.G. Ranney, and D. Touchell. 2021. Radiative Balance of Different Miscanthus Hybrids. ASA-CSSA-SSSA International Annual Meetings, Salt Lake City, UT.

Carvalho, H.D.R., J.L. Heitman, A.M. Howard, A. Johnson, C. Crozier, M. Chinn, and C. Sayde. 2021. Energy Balance of Miscanthus and Corn in North Carolina. ASA-CSSA-SSSA International Annual Meetings, Salt Lake City, UT.

Carvalho, H.D.R., J.L. Heitman, A.M. Howard, C. Sayde, A. Johnson, C.R. Crozier, and M.S. Chinn. 2021. Evapotranspiration from Miscanthus and Corn Fields in North Carolina. SSS-NC Annual Meeting. Virtual.

Kranz, C.N., J.L. Heitman, and R.A. McLaughlin. 2021. Amending Roadside Soils with Compost: Effects on Runoff Quality and Quantity, and Vegetation Establishment. ASA-CSSA-SSSA Annual meeting, Salt Lake City, UT.

Kranz, C.N., J.L. Heitman, and R.A. McLaughlin. 2021. Managing Stormwater Quantity and Quality with Compost Incorporation. North Carolina Department of Transportation Summit, Virtual conference.

Kranz, C.N., J.L. Heitman, and R.A. McLaughlin. 2021. Compost Incorporation on Roadsides for Soil Improvements and as a Stormwater Control Measure. International Conference on Ecology and Transportation, Virtual conference.

Kranz, C.N., J.L. Heitman, and R.A. McLaughlin. 2021. Review of Incorporating Compost into North Carolina Roadsides. *International Erosion Control Association Annual Conference. Virtual*.

Kranz, C.N., J.L. Heitman, and R.A. McLaughlin. 2021. Organic amendments for soil restoration on North Carolina Roadsides: A review. SSS-NC Annual Meeting. Virtual.

Mathers, C., A. Woodley, and J.L. Heitman 2021. When soil health metrics don’t account for yield stability differences, what does? ASA-CSSA-SSSA Annual meeting, Salt Lake City, UT.

Mathers, C. A. Woodley, J.L. Heitman, and A. Huseth. 2021. Influence of Cover Crops on Water Storage in Water-Insecure Environments. SSS-NC Annual Meeting. Virtual.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

Soil processes for agricultural, engineered, and natural systems are greatly affected by dynamic soil arrangement (i.e., the structure and density of soil). NC State researchers have developed a framework for measuring and modeling these dynamic soil parameters that has the potential to be integrated into crop and soil management models. NC State researchers also analyzed the effectiveness of compost in reducing runoff, improving runoff quality, and increasing the establishment of vegetation in unstable subsoil conditions, and have demonstrated that compost incorporation via tillage was an effective management strategy. This research was shared through 14 refereed research publications and through presentations at scientific meetings, and it lays groundwork for enhanced monitoring and management of soil resources, particularly in degraded soil environments. This is just one example of how NC State is translating research into practical solutions that address grand challenges in agriculture.

Closing Out (end date 09/07/2023)

Pesticide and trace element fate and behavior in the environment

Project Director

Travis Gannon

Organization

North Carolina State University

Accession Number

1017318

Understanding pesticide environmental fate and behavior

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Pesticides are viable management tools in agriculture but must be utilized appropriately to prevent environmental contamination while meeting agronomic goals. Society relies on synthetic pesticides for food and fiber production as well as management of noncropland areas. Understanding pesticide environmental fate and behavior is of utmost importance to ensure we do not adversely affect human or environmental health.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Collaborative original and scholarly research related to pesticide and trace element environmental fate and behavior was initiated. This research team's work to characterize the fate and behavior of experimental and recently registered pesticides, as well as organic arsenical herbicides is underway. Much of this research was framed around understanding fate and behavior as it may affect efficacy, environmental health and human health to assist in devising comprehensive best management practices to ensure pesticides do not adversely affect human or environmental health. Collaborative research in this project also includes leading a portion of a USDA-SCRI grant investigating mechanisms of annual bluegrass herbicide resistance in various turfgrass systems. The research has been completed while training undergraduate and graduate students. Conduct research investigating pesticide fate and behavior in various crop and specialty systems.

By characterizing the fate and behavior of pesticides among various systems and seasons, evaluating the potential of various pesticides to cause adverse effects on nontarget species, determining if select herbicides may cause adverse effects to subsequent cropping systems, and conducting research exploring trace element behavior in various systems; research focused on the behavior and fate of trace elements as well as remediation efforts of contaminated systems including phytoremediation has significantly benefited growers. To this end researchers have been working to evaluate various species for phytoremediation potential and determine the effect of soil chemical and physical properties as well as chelants on trace element solubility and extractability. This provides a direct benefit to growers through the development of appropriate best management practices to effectively utilize pesticides without adversely affecting human or environmental health.

Briefly describe how your target audience benefited from your project's activities.

With a thorough understanding of pesticide environmental fate and behavior, producers and land managers are able to effectively use pesticides to manage pests economically without adversely affecting off-target species or other components of the ecosystem, as well as human health. Further, producers and land managers are able to optimize pesticide efficacy and reduce inputs based on best management practices developed based on our research. Similarly, a thorough understanding of trace element behavior will ensure individuals aren't exposed because of current management programs or inputs.

Briefly describe how the broader public benefited from your project's activities.

This research addresses contemporary issues pertaining to the safe and effective use of pesticides in today's society while addressing grower and various stakeholder concerns.

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

Understanding the impact of pesticides on the environment is critical in order to avoid adversely affecting human or environmental health while meeting agronomic goals. NC State researchers are working to characterize the fate and behavior of experimental and recently registered pesticides, as well as organic arsenic-based herbicides. Collaborative research in this project also includes leading a portion of a USDA-SCRI grant investigating the mechanisms of annual bluegrass herbicide resistance in various crop and specialty systems. By characterizing the fate and behavior of pesticides and trace pesticide components among various systems and seasons, evaluating the potential of various pesticides to cause adverse effects on nontarget species, and determining if certain herbicides may cause adverse effects in subsequent cropping systems, NC State researchers are guiding the development of new best management practices that significantly benefit growers. These practices include the use of phytoremediation, a plant-based approach to removing or limiting the effects of pollutants in soil, and the use of chemicals to extract trace pollutants from soils. Helping growers more safely and effectively use pesticides is just one example of how NC State is growing the future of NC agriculture and serving all North Carolinians.

Keeping afloat in the data deluge: coupling observational data, analytics, and integrated models to propel data-driven biological resources management

Project Director
Natalie Nelson
Organization
North Carolina State University
Accession Number
1016068

Results for Project Period 10/1/2020 - 9/30/2021

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

The primary goal of this project is to advance biological resource management through data-intensive analyses by bringing data science into the fore of biological systems research. To meet this goal, data science approaches will be applied to observational and empirical data collected across a range of biological systems (estimated at 5-15 distinct system types) in order to present a series of case studies that showcase the utility of data science in biological resources management. These case studies will include collaborators who investigate biological system dynamics but have not incorporated data science approaches in their work, thereby growing the network of researchers and practitioners who have an understanding of the utility of such approaches.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Multiple proposals were submitted and included new collaborations. The following proposals were awarded during the reporting period: Project title: Towards Real-Time Fecal Indicator Bacteria Monitoring in Nearshore Waters. Sponsor: NCSU Research and Innovation Seed Funding Program. Hatch PI served as proposal PI. Project title: A Framework for Monitoring, Prediction and Assessment to Support Decision-Makers Needs for Coastal and Ocean Data and Tools. Sponsor: Southeast Coastal Ocean Observing Regional Association. Hatch PI served as proposal PI. Project title: CAREER: Characterizing the Unseen Water Quality Consequences of Sunny-Day Floods in Nearshore Waters. Sponsor: National Science Foundation. Hatch

PI served as proposal PI. Project title: STC: Science and Technologies for Phosphorus Sustainability (STEPS) Center. Sponsor: National Science Foundation. Hatch PI served as proposal Co-PI. Project title: Cultivating A Resilient Workforce By Integrating A Culturally Competent Community Of Scholarship & Data Science in Food & Agricultural Research. Sponsor: USDA NIFA. Hatch PI served as proposal Co-PI. Project title: Harmful Algal Bloom Observing Network for the Caloosatchee Estuary. Sponsor: US Environmental Protection Agency. Hatch PI served as proposal Co-PI. Project title: Future Ready Farmer's Almanac. Sponsor: NCSU Research and Innovation Seed Funding Program. Hatch PI served as proposal Co-PI. Project title: Coupling Lake, Watershed, and Estuarine Models to Better Understand the Role of Engineered Freshwater Discharges in Driving the Severity, Location, and Timing of Harmful Algal Blooms. Sponsor: US Army Corps of Engineers Engineer Research and Development Center. Hatch PI served as proposal Co-PI. Project title: Piloting a Data Science Extension Program to Advance Data-Driven Soybean Production. Sponsor: United Soybean Board. Hatch PI served as proposal Co-PI. Project title: Leveraging Real-Time Insect Traps and Data Analytics to Improve Corn Earworm Risk Prediction. Sponsor: NC Soybean Producers Association, Inc. Hatch PI served as proposal Co-PI. Project title: Integrated Decision Support and Management Tools for Adaptive Public Health Practices: An Early Advisement and Reporting System for Recreational and Shellfish Harvesting Waters of the Southeast. Sponsor: Southeast Coastal Ocean Observing Regional Association. Hatch PI served as proposal Co-PI.

Briefly describe how your target audience benefited from your project's activities.

The PI: • Provided professional development opportunities to students (5 PhD, 2 MS, 6 undergarduate) and a postdoctoral researcher through research mentoring; • Attended the Annual International Meeting of the American Society of Agricultural and Biological Engineers and the Fall Meeting of the American Geophysical Union; • Served as a panelist for an AFRI program and an ad-hoc reviewer for NSF; • Served as the Faculty Advisor for the NC State Student Chapter of Alpha Epsilon, the honors society of the American Society of Agricultural and Biological Engineers; • Published a peer-reviewed teaching module in Transactions of the ASABE, which included an exercise for teaching students how to organize and analyze environmental data in R; • Led a USDA NIFA-funded Research and Extension Experience for Undergraduates program, which trained 10 undergraduate students with interests in food animal production in the principles of data science; • Taught two university courses: BAE 565 Environmental and Agricultural Analytics and Modeling, and BAE 495/590 R Coding for Environmental and Agricultural Data Management and Analysis. BAE 495/590 included registrants who were working professionals, including an Extension agent, as well as undergraduate and graduate students.

Briefly describe how the broader public benefited from your project's activities.

Results were disseminated through publications and presentations (see reported products).

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Continue to meet with potential collaborators who are working across a range of study systems • Continue to mentor graduate and undergraduate students in the application of data science to research biological system dynamics • Analyze data collected from a range of biological systems to inform improvements to biological resources management • Publish articles and Extension fact sheets, and deliver oral presentations at local and national conferences to disseminate research findings • Submit proposals to secure additional extramural funding for project studies

Impact Statement (Optional)

Use this space to talk about the impact that this result had, in layman's terms. Adding comments here will **not** change the content in the highlighted result.

To advance biological resource management, NC State researchers are bringing data science into the fore of biological systems research by developing and presenting a series of case studies to demonstrate how practitioners can extract useful information from raw data, including satellite imagery, high-frequency measurements collected in the field, and long-term monitoring records. These case studies include monitoring coastal and ocean data, helping shellfish producers forecast weather to optimize harvest schedules and other operations, using data science to cultivate a resilient agricultural workforce, observing harmful algae, and advancing data-driven sweetpotato production. NC State researchers also provided professional development opportunities to instruct 5 PhDs, 2 master's degree students, 6 undergraduate students, and a postdoctoral researcher in best practices for environmental and agricultural data analysis and led a USDA NIFA-funded research and Extension experience to train an additional 10 undergraduates in the principles of data science. This is just one example of how NC State's trusted cutting-edge, solution-driven research is fueling agricultural and environmental sustainability throughout the state and empowering better-informed decisions.

Type	Projects / Programs
Projects / Programs without a Critical Issue	**0**

Not Provided