North Carolina (North Carolina Agricultural and Technical State University, North Carolina State University Combined) Annual Report - FY2022

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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 transforms science into everyday solutions that is extended to all North Carolinians to improve lives and grow our state through N.C. Cooperative Extension.

NC State: From the food that nourishes us and the fiber that clothes us to the ornamentals that brighten our lives and provide ecosystem services – we work on the plants, animals and microbes that sustain us. We live our land-grant mission, supporting individuals, families, communities and businesses in our constant quest to improve lives and provide opportunities for all across our state. We research the basic fundamentals of biology, agriculture and ecosystems; of family and community dynamics; of physics, data and technology; and of educational and extension theory. We turn that basic knowledge into innovation that delivers new technologies, new crops and livestock, new processes, and new ways of addressing challenges on our farms and in our homes, communities and businesses. We bring knowledge to our students and external constituents, and we educate and train the people who make all of this happen. Throughout 2022, the North Carolina Agricultural Research Service (NCARS) and NC State Extension prioritized efforts aimed at solving the complex challenges facing food and agriculture.

N.C. A&T: Fiscal Year 2022 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. N.C. A& T researchers are working to find the solution from food production, food safety to post harvest, alternative energy, obesity, Ag economics and needs of community. Cooperative Extension at N. C. A&T State University provides research-based information and educational programs to North Carolinians with social, cultural, and economic barriers to upward mobility. With our assistance, these North Carolinians—families, youth and the elderly, urban and rural and from diverse backgrounds—have the skills to make decisions that improve their communities and their lives. Our programs address all the critical issues that impact small farmers and their communities, including agricultural sustainability, access to healthy foods in food insecure regions, nutrition and health, and providing opportunities for youth to thrive. We work closely with researchers in the College of Agriculture and Environmental Sciences to see that their work in improving crops, introducing new niche crops, improving agriculture practices, protecting the environment, and finding new markets makes its way to the producers in our state so they can continually improve and grow. Cooperative Extension at N.C. A&T promote community health and fight the epidemic of obesity in lower-income communities through nutrition programs and community gardens. We provide opportunities for thousands of youth through 4-H and its many programs in STEM and leadership development. And we help people who have rarely been heard at the community level find their voices, get heard, and grow into leaders and mentors. We touch the lives of students and retirees, parents and young children, farmers and entrepreneurs, community leaders, and neighbors looking for better lives. We've worked for North Carolinians for well over 100 years, and we will continue to work with them to find answers to the challenges we face in agriculture, food systems, youth development, and community leadership.

Critical Issue: Enhancing Food Safety, Nutrition and Health

NC State: NC State researchers are developing and using CRISPR-based gene editing technologies to study and modify bacterial strains and develop novel technologies that enable genetic manipulation of food microbes for use in fermentation and as probiotics. Researchers also conducted studies on consumer insights and the sensory quality of plant-based dairy alternatives (PBDAs) and dairy

products with reduced sugar and that offer immune-boosting and calming effects. Research found that taste remains the driving force for consumer preference, and the use of a natural low-calorie sweetener that delivers the sensory experience of sugar is more important than familiarity with the sweetener. Researchers from NC State worked to address the problems caused by conventional food processing which degrades flavor, color, quality, and nutritional value. Researchers developed a new, energy-efficient microwave heating technology, followed by packaging into flexible, sterile packaging. In 2022, two processing facilities employing this technology were constructed and put into operation, one in NC and another in Kenya. In addition to maximizing the preservation of sensitive flavors and nutrients and extending shelf life without refrigeration, this technology minimizes or eliminates food waste and reduces processing time and costs. NC State researchers invented a new process for infusing fruit flavors and nutrients into coffee beverages to enhance the quality of coffee products. They also demonstrated the effectiveness of a new microwave coffee extraction method and are investigating sustainable, low-water-use methods of coffee production. In addition, researchers completed a clinical trial on the effects of coffee on blood sugar regulation, and they completed a joint clinical trial with Elon University examining the effects of coffee and coffee roasting methods on athletic performance.

To promote health and wellness, prevent chronic disease, and increase access to healthy foods, NC State Extension delivered a combination of research-based direct educational programs and policy, systems and environmental change efforts. Extension faculty participated in a national Policy, Systems, and Environmental Change (PSE) collaborative group with other Extension health specialists to discuss how to better implement PSE changes through Extension across the U.S. The group is working to better understand whether Extension agents are adopting PSE changes, what training they need, and programmatic needs to better support implementation of PSE changes to support access to healthy foods and places to be active. As a result of NC State Extension programs, 59,225 adults increased their fruit and vegetable consumption, 6,328 increased their physical activity, and 3,924 consumed less sugar in their diet.

NC State Extension specialists are working to establish a Food Safety Extension Network of institutions across the southeast to synergistically advance the science of consumer and retail/food service food safety and share expertise, training, and developed materials across the Land-grant system. Collaborators include institutions from the southern region. To also assist with promoting healthy diets and to reduce instances of foodborne illness, NC State Extension developed resources and provided training on food preparation and food safety. As a result, 20,693 participants increased their knowledge of how to prepare foods, including home food preservation techniques and 22,632 participants increased their knowledge of safe home food handling, preservation, or preparation practices.

N.C. A&T: N.C. A&T Researchers studied the environment friendly way to get rid of pest, insect, and mold from the stored cereal grain where cinnamon, thyme and clove proved most effective in controlling both insecticide and fungicide effect without any change in shelf life of organic corn. Other research projects in this integrative cluster area included development of a novel frying medium to reduce the fat in fried chicken and fish where researchers are using the frying medium based on oleogel, study to add the shelf life of food containing probiotic, investigating the efficient and cost-effective way to deliver a bioactive through a food, identification of dietary compounds that can be obtained from parts of food plants typically discarded that have the potential to prevent obesity, study of 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. In the study of disinfectant, the result showed that hemp can be a viable option for reducing the proliferation of SARS-CoV-2.

N.C. A&T Extension programs in this area focused on reducing nutrition to reduce the rates of chronic diseases, and addressing food insecurity, food safety, and nutrition. Hundreds of community participants learned about the importance of eating fruit and vegetables, how to reduce sodium and sugar in their diets, safe food preservation techniques, and how to add exercise into their daily routines. Try Healthy, Extension's Supplemental Nutrition Assistance Program- Education (SNAP-ED), helped people with limited resources make healthier food choices and increase physical activity, Healthy Habits, the youth component of SNAP-ED, trained five teen ambassadors and reached 2,476 youth using the Go, Glow, Grow, and Teen Cuisine curricula. The Expanded Food and Nutrition Education Program (EFNEP) addressed the problem of food insecurity and limited nutrition knowledge among low-income families by utilizing various nutrition curricula. In 2022, EFNEP educators in five counties provided education on nutrition, budgeting, meal planning, and connecting to community resources.

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

NC State: To strengthen local food systems five counties launched a Donation Station program, and two counties continued the program from 2021, facilitating donations of healthy local food to food-insecure families while supporting farmers through the purchase of 4,459lbs of local food. To support rural development, Extension specialists and agents supported local development committees in local economic development assessment and planning. They also presented workshops on developing and improving agritourism and other

tourism businesses and the use of tourism marketing platforms. The CREATE BRIDGES program is facilitating strategic plan development and implementation in the mountain west region of North Carolina as part of the national pilot of the CREATE BRIDGES program. Other states participating include New Mexico, Illinois, Arkansas, Kentucky, and Illinois.

Extension professionals also delivered an array of programming to assist individuals and families. As a result, 7,400 people gained knowledge and/or skills to increase family economic security. In addition, nearly 2,500 adults increased knowledge of life skills, such as goal setting, stress management, self-care, and healthy relationships. Extension provided programs for older adults to help reduce falls and help them age in place and improve their strength, flexibility, and balance. Specialists are participating in the Healthy Homes Partnership; a national collaboration between NIFA, USDA, and Extension. States in the partnership include North Carolina, Florida, Georgia, Alaska, Connecticut, Louisiana, Montana, Missouri, Tennessee, and Oklahoma. As part of this initiative, NC State partnered with University of Georgia Extension on Portable Generator Safety Training. This multi-state effort is a direct result of the Healthy Homes Partnership and is an effort to address common issues for those in the Southeast. NC State researchers have discovered insights into potential new approaches to controlling bed bugs and cockroaches. They discovered that cockroaches are highly susceptible to fungal infections and developed a deeper understanding of why cockroaches rapidly evolve high levels of resistance to some insecticides and not others. Researchers analyzed bed bug production of histamine to better understand the health risks associated with histamine and support potential mitigation approaches.

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. For example, North Carolina 4-H focused on educating youth on the importance of voting by promoting the Kids Voting NC program to create lifelong voting habits in children, increase family communication about citizenship, and encourage greater adult voter turnout. Youth across NC also participated in livestock, poultry, and small animal shows and judging; 4-H projects; and clubs among many other animal science programs. Statewide, Extension youth animal programs had over 26,000 youth participants. In collaboration with Kentucky State University, University of Florida, Mississippi State, Georgia Southern University, and Middle Tennessee State University on STEMSATIONAL AG, Extension specialists are producing both formal and non-formal agricultural educational content for K-14 students that is appropriate for traditional school settings, as well as accommodate distance, in-person, and homeschooled children in the Southeast Region. NC State specialists have served on the management team for the Volunteer Conference of Southern States, a regional 4-H volunteer-led training event featuring a hybrid delivery of more than 60 learning experiences over the four-day experience.

N.C. A&T: Research in this integrative cluster area included community engagement like working with residents to improve their lifestyles and eating habits, addressing the nutrition, well-being through training and workshops, working with both the consumer and producer to enhance farm profitability by using value added products. Also, researchers are trying to identify how the home environment influences the daily life of elderly low-income homeowners.

Extension offered a variety of opportunities for youth through its 4-H program. Many programs focused on building leadership skills and exposing youth to science, technology, engineering, and math (STEM). A new program called 4-H Tech Changemakers trained tech savvy teens to teach computer and other digital skills to adults in their communities, with the goals of helping adults better utilize technology to find jobs while building young community leaders who can help bridge the digital divide. The 4-H Robotics Program, which teaches coding and other skills needed to build simple robots, reached 632 youth and offered summer camps where youth build robots to perform specific tasks and develop their teamwork and leadership skills. A pilot program called Youth Stepping Forward taught 100 minority and limited-income youth to be leaders and decision makers as they worked together to address a community issue. Extension also works to develop adult community leaders and address food insecurity through its Community Garden Program and the Community Garden Leadership Academy (CGLA), which offers training to community garden leaders and helps build a network of leaders who are engaged with their communities and work collaboratively to address food insecurity. The CGLA currently has 214 active members, up from 112 members in 2021.

Critical Issue: Improving Plant and Animal Agricultural Systems

NC State: NC State researchers are using genetic engineering technology to create better tasting peanut varieties resistant to environmental stresses like drought and disease by fortifying the Bailey cultivar with genetic resistance to late leaf spot, a common, fast-moving disease that costs growers an estimated $53 million annually. To fight pests, NC State researchers are investigating nematodes' biological characteristics, modeling crop losses in relation to plant-parasitic nematode (PPN) populations and evaluating management methods. NC State researchers conducted studies to determine the population distribution of the brown marmorated stink bug (BMSB) in NC and established an effective model to predict BMSB population development, providing growers with a new tool for precisely timing insecticide applications for maximum efficiency. Researchers and Extension specialists are working on a 29-state project to monitor downy mildew on cucurbit outbreaks, coordinate state activities, identify management solutions, and educate growers on disease

management and identification. Researchers are studying diseases of sweet potato and secured registration for five new fungicides to combat the epidemic of sweet potato black rot, reducing disease losses from 40% to 5% and preventing an estimated $116 million in losses for NC growers. NC State participates in the National Sweetpotato Collaborators Group, the only national group that focuses exclusively on sweetpotato research and extension activities. A team of 16 scientists across 15 universities are involved in a four-year project to limit the impact of the weed annual bluegrass, known as Poa annua, which has grown to epidemic proportions, causing severe economic losses and is the most troublesome weed of athletic, golf, lawn and sod.

NC State researchers and Extension specialists used applied research and on-farm and official variety testing to develop new varieties, products, technology, and research-based agronomic crop best management practices (BMPs) to support growth in row crop production and assist growers in addressing their technological, biological, and environmental challenges. Extension specialists and agents transferred knowledge of these innovations and practices to producers. As a result of NC State Extension programs, over 25,000 crop producers increased knowledge, attitudes, and/or skills related to best management production practices; pest/insect, disease, weed, and wildlife management; financial/farm management tools and practices; and alternative agriculture, bioenergy, and value-added enterprises. NC State Extension's commercial and consumer horticulture programs resulted in over 425,000 participants gaining knowledge of landscape, turf, and garden best management practices; over 100,000 participants adopting practices; and nearly 55,000 participants selecting appropriate landscape plants after participating in Extension consumer horticulture programs.

In the area of animal agriculture, NC State researchers discovered new ways to use animal manure and other animal production byproducts including using swine lagoon sludge to create low-cost compost materials, systems for processing lagoon sludge into a compact and exportable form, and the development of a simulation tool to help predict impacts of future climate conditions on animal production lagoons and storage ponds. Extension helped pork producers by providing assistance with a broad range of tasks, including sludge management, irrigation and litter calibration, record-keeping, manure sampling, general permits, and nutrient management plans. Extension helped pork producers apply for over $2.7 million in assistance covering lost income, lagoon closure costs, and barn renovation costs. Following Extension training and outreach efforts across the state, over 2,000 producers increased their knowledge of animal waste management practices, 4,583 animal waste management credits were earned, 192 on-site sludge surveys or equipment calibrations were conducted, and 178 waste utilization/waste management plans were developed or updated. To address a 2022 uptick in highly pathogenic avian influenza (HPAI) and mitigate harm to NC's nearly $40 billion commercial poultry industry, Extension collaborated with industry partners to encourage producers to establish and follow strict biosecurity protocols. NC State Extension provided educational programs and technical assistance resulting in 6,975 producers increasing knowledge of pasture/forage management practices, 4,614 producers increasing knowledge of nutrition and breeding, and 5,033 producers increasing knowledge of strategies for promoting animal health and welfare.

N.C. A&T: Research projects in this integrative cluster area focused on plant/crop production and animal systems. Researchers are studying soil health, environmental benefits of CBD hemp production and physiological development of hemp. The hemp was planted using different treatments to examine the differences in soil, biological activity, plant biomass and CBD production. Researchers are investigating to find an environmentally friendly way to manage pests in vegetables (crucifer, cowpea, greens beans, eggplant, sweet potato). Researchers are evaluating ginger cultivars and tissue culture ginger to find ginger with higher health benefit. Other research related to plant and crop production included the study of development of physiological development and cold and heat tolerance green leafy vegetables, best management practices to grow tuber borchii truffles, season extension using plastic film layers to grow tomatoes. In the study relating to animal system researchers studied immune's system response to disease pathogens in ruminants to help determine ways to control and prevent disease, researchers are using garlic as the alternative to anibiotics. Other research related to animal systems focused on the use of agricultural residue and crop extract (onion peel) to produce antibiotic free poultry, improving the physical, reproductive, milk composition and gut health of animals by identifying plant-based feed supplement, and reducing the greenhouse gas emission by using plant-based feed. The result showed the plant-based feed is helping to reduce greenhouse gas emissions. Also, researchers are studying U.S. and foreign governments' policies on U.S. food and agricultural trade, the economy, and the environment; according to researchers the prices of Meat and Poultry Products in Covid era was more than 20% higher than the post. Among the meat products, beef saw the highest price hike.

Cooperative Extension used hands-on and classroom training to reach small farmers, with a focus on those in underserved and minority communities. New programs were launched during the year, including the Small Farms Leadership 360 Initiative, which offered training in farm business management, marketing and sales, networking, environmental sustainability, and more in four in-person, hands-on learning modules. Extension also presented its first-ever Niche Agriculture Conference, where small, limited-income farmers learned how niche crops such as ginger, microgreens, and cut flowers can increase profitability. Several Extension programs focused on helping farmers succeed in a market that values organic and sustainable practices. Farmers learned about using diverse plants with overlapping

and successional blooms through the growing season to provide shelter and nesting sites for pollinators and natural enemies (predators and parasitoids) of crop pests. Extension also continued to offer its Plasticulture/Rental Cash Back Program, which provides small farmers with low-cost equipment and training so they can use plasticulture to increase yields, control weeds and pests, and reduce water usage.

Critical Issue: Protecting Environmental and Natural Resources

NC State: NC State researchers have analyzed data from natural and agricultural systems that are increasingly monitored through wide-ranging sensors, including those on satellites and installed in the field. Diverse environmental and agricultural datasets have been created using methods such as machine learning and statistical modeling. Advantages gained from this research include the creation of a harvest closure forecasting system and accompanying web application for shellfish producers and the creation of various fact sheets to make data analysis tools more accessible. To help reduce the environmental impact of carbon dioxide, NC State researchers are developing a method to enhance plants' natural ability to pull carbon dioxide from the atmosphere. In addition to benefiting the environment, this method has the potential to increase the growth rate of biofuel and food crops. NC State researchers have advanced the field of ecology by identifying models that can anticipate the ecosystem consequences of changes in species' communities and developing models to predict territorial spread and competition among species. Researchers have also provided proof-of-concept for a new method to accelerate the biological recovery of stream-dwelling insects, assess restoration success, and import restoration techniques to freshwater fisheries.

NC State Extension agents offered a variety of programs addressing issues related to environmental protection. As a result of this programming, 13,696 participants demonstrated increased knowledge of climate mitigation practices, and 3,677 participants expressed a willingness to adopt conservation actions. Specialists continued collaboration with University of Maryland on a joint presentation to the Southern Extension Economics Committee on solar development and decommission. In partnership with the NCDA&CS, Extension Pesticide Schools served a total of 1,455 attendees. Extension also led efforts to counteract the environmental effects of extreme rainfall, reduce stormwater runoff pollution from growing communities, and support urban sustainability and water quality. Extension trained and certified 5,465 individuals, including over 20 HOAs, in stormwater control measure inspection and maintenance. Extension's Forestry program educated more than 95,901 landowners, land managers, and other community members across the Southern US about the importance of prescribed fire in forest management, and 37 landowners and professionals learned practical skills to better protect the forests around their homes from wildfires. Forestry programs in 2022 increased the knowledge of approximately 115 Extension agents and agency partners on forest health through 3 workshops in the Carolinas. Extension Forestry also continued to conduct forest health programming to increase knowledge of invasive species. These outreach efforts helped over 235,000 people increase their awareness of the impact of invasive species on local forests.

N.C. A&T: Research in this integrative cluster area focused on water quality and clean energy. Researchers are studying the engineering technique to improve the on-farm water quality and develop a biorefinery to produce bioelectricity, renewable natural gas, microalgae, and clean water from various agricultural wastes. Researchers are studying different environmentally friendly techniques to remove pathogens and pesticides from wetlands and farm ponds. Another group of researchers are studying the potential ways to convert carbon content waste from swine manure, oakwood, miscanthus to advanced multifunctional carbon nanomaterial where they developed magnetic biochar-based carbon materials for removing phosphate from wastewater. Researchers also developed novel N-doped carbon nanofibers for high performance capacitors.

Extension programs in this area focused on resilience in the face of climate change and management of natural resources to maintain the quality of farmland and water. Extension agents distributed soil testing kits and learned about management practices that protect soil and water resources, and the advantages of using high tunnels and cover crops. Extension agents partnered with CAES researchers to demonstrate successful growing of niche crops, high tunnel production, organic production, and climate smart practices. To address the decline of honeybees across the nation, Extension agents held monthly meetings with beekeeper associations in four counties. They also provided training and technical assistance and conducted an annual beekeeping school, making more than 750 contacts through 37 interactions.

Merit and Scientific Peer Review Processes

Updates

NC State: None

N.C. A&T: None

Stakeholder Input

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

NC State: None

N.C. A&T: None

Methods to identify individuals and groups and brief explanation

NC State: NC State used a newly implemented electronic mailing system, Active Campaign, to send surveys to all clients subscribed to Extension mailing lists and clients who attended Extension programs, to identify needs and assist in the planning process.

N.C. A&T: None

Methods for collecting stakeholder input and brief explanation

NC State: In addition to the methods identified in our Plan of Work, as part of our 2022 strategic planning process stakeholder input was gathered from over 700 faculty, staff, and student survey responses, over 9,000 Extension stakeholder survey responses, over 70 interviews, 9 focus groups with CALS faculty, staff and students and 14 stakeholder listening sessions.

N.C. A&T: None

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

NC State: Input from stakeholders was used to develop CALS and **NC State Extension** strategic plans to identify issues and guide initiatives through 2030. The development of these two strategic plans was intentionally designed with a bottom-up approach, giving all a voice. Over 11,000 people provided input and data that have been crucial in helping elevate focus areas, topics and initiatives.

N.C. A&T: Input from stakeholders was used to determine program and research priorities, address community needs, and continuously drive strategic planning.

Highlighted Results by Project or Program

Critical Issue

Enhancing Food Safety, Nutrition and Health

Oleogel delivery system: Improving stability and bioaccessibility of bioactives
Project Director
Roberta Claro da Silva
Organization
North Carolina Agricultural and Technical State University
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Oleogel delivery system: Improving stability and bioaccessibility of bioactives

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

The consumption of bioactive compounds has been associated with several health benefits to consumers. However, despite their natural occurrence in foods, bioactive compounds typically occur in limited amounts, too small to reach an effective concentration and provide these benefits. Moreover, in their natural form in foods, the majority are unstable and easily oxidized under various conditions, especially when exposed to the combination of oxygen, light, and/or heat during processing and storage. Also, they show low water solubility, poor bioavailability, and insufficient dispersibility. Besides all these limitations, they can interact with some food ingredients and cause unfavorable effects on the sensory attributes of food products. To increase their beneficial effects and consequently improve consumers' health, a system to protect and stabilize these compounds in foods needs to be developed. However, a system for viably delivering bioactive adding high safety and low production cost for foods does not yet exist. *Thus, this project aims to research and develop a natural, cost-effective, and efficient encapsulation technology for delivering bioactive that can be incorporated into food products.*

In order to meet the growing need for healthy food, our research will include the development of new food products that promote health and prevent disease through the development of an innovative *oleogel delivery system* to carry the bioactive curcumin. Thus the consumption of food products contained curcumin-oleogel will enhance the optimal potential of therapeutic effects of the bioactive, such as prevention and treatment of various diseases ranging from cancer to autoimmune, neurological, cardiovascular diseases, and diabetes (Aggarwal & Harikumar, 2009; Shehzad et al., 2010, 2011; Kocaadam & Sanlier, 2017). Besides that, the oleogel system added to the food matrices will reduce the saturated fat content of processed foods, which is one of the American Heart Association (AHA) recommendations to reduce the risk of cardiovascular disease. In addition, the information gained from the research can be used to educate consumers about the health benefits of bioactive. By creating this technology, we will strengthen the importance of *lipid chemistry* research for the Food and Nutrition Sciences Program at North Carolina A&T State University and also establish a new branch of interdisciplinary research into *functional foods* at North Carolina A&T State University, enhancing the capacity of the Food and Nutritional Sciences program to innovate within the Food Safety, Nutrition and Health research cluster.

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 goal of this project is to develop a natural, cost-effective and efficient encapsulation technology for the delivery of bioactive that can be incorporated into food products.

During the period of this report, we worked on the following objectives to accomplish the main goal:

To accomplish this goal, we worked on the following objective:

1. To develop stable and semi-solid oleogels and evaluate their physical-chemical properties, encapsulation efficiency, and loading capacity**.**

Physical stability of the oleogels

To find the best combination of oils and oleogelators, we evaluated the physical properties (texture, oil binding capacity, visual appearance, microscopy, and melting profile) of 20 oleogels. Two oils were studied (corn and sunflower oils) and two oleogelators (rice bran wax and carnauba wax) in different percentages (2,4,6, and 10%).

The oil binding capacity (OBC) test represents how much oil is entrapped in the oleogel net, which was enhanced with the increase of carnauba wax %. Therefore, the oil binding capacity was not dependent of the storage time.

The rice bran wax was effective even in lower concentrations (2, and 4%) entrapping all the oil for 90 days. The visual results are similar to those observed in the OBC results in which carnauba wax produced a stable oleogel only with a 10% addition.

The % added of carnauba wax does not affect the melting properties of the oleogels (*tonset or tpeak*), otherwise the % of rice bran wax affects the melting curves of the oleogel. The addition of 10% rice bran wax delayed the melting temperatures by 11 °C compared to the oleogel containing 2% rice bran wax. Confirming the results observed in the OBC and microscopy, the carnauba wax only produced a harder oleogel in the high amounts (6 and 10%). Otherwise, the rice bran wax produced harder oleogels than carnauba wax, even in low amounts, structuring corn and sunflower oil. Rice bran wax at 6% has similar texture characteristics to carnauba wax at 10%.

Carnauba oleogels show spherulitic microstructures that grow in size with the increase in the amount of wax. Adding 6 and 10% of carnauba wax, the spherulites seem to be more linked, which justifies the higher OBC results.

For the physical stability properties, the results of this study show that both waxes can structure corn and sunflower oils. However, the carnauba should be used in higher percentages, which can affect the sensory properties of the foods. Carnauba wax at 10% of addition has a similar texture profile to 6% rice bran wax.

Chemical stability of oleogels

To find the oleogels chemical stability (peroxide value), an accelerated oxidation test were performed for 60 days. The findings show that rice bran wax oleogel samples had the lowest peroxide values than carnauba wax samples indicating that the addition of rice bran wax has a protective effect on the oils against oxidation.

Addition of curcumin to the oleogels

To study the effect of curcumin on oleogels stability, the tests were conducted on all the oleogels added of 0.1, 0.2, 0.4 and 0.8 of curcumin.

The finds show that the addition of curcumin slightly affected the physical properties of the oleogels with lower percentages of waxes (2 and 4%). However, in higher percentages, no significant differences were observed.

The accelerated oxidation test shows a protective effect of the curcumin for the degradation of the oleogels. However, the protective effects were different for rice bran and carnauba waxes. For example, the lowest peroxide value (oxidation test) was found for 6% carnauba wax oleogel added of 0.4% curcumin sample storage at 60 °C. On the other hand, in the rice bran wax sample, the lowest peroxide value was observed in the sample containing 4% rice bran wax and 0.2% curcumin. However, comparing these two waxes, the rice bran wax oleogel sample had the lowest result than the carnauba wax sample. Moreover, to get the lowest oxidation rate, we need a low amount of wax and curcumin for the rice bran wax oleogel.

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

Food industries and consumers in the United States are the main stakeholders of this proposal, and they will benefit from the new technology of oleogelation to be developed. The findings will allow the industry to improve the health benefits of food products, reducing saturated and trans fats, adding bioactive with higher performance to humans, and improving the shelf life of the products under storage. Consequently, the outcomes of this project are contributing to the health of the citizenry of the U.S.

The project's first-year results show that the oleogels combination studied was a stable source of fat to substitute saturated fats and can successfully work as a delivery system for curcumin.

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

Several societal and economic benefits have been identified that could occur due to this project. Consumption of bioactive has been associated with health benefits. However, the way that bioactive is consumed now does not allow us to reach full benefits. The development of a novel system to improve the bioavailability and stability of bioactive can lead to a revolutionary change in the nutrition quality of processed food with an increase in health benefits. In addition to these highly significant societal benefits, the potential economic benefits are also significant. Thus, a far greater impact on health could be realized by incorporating oleogel technology into staple foods such as bakery products. As part of the follow-up of this project, we would look to engage with food manufacturers who would test the oleogel technology in a range of prototype food products. Further societal benefits can be accrued through public engagement. The area of food and nutritional sciences is of great interest to the general public.

The results generated in the first year of this project showed that the oleogel loaded with curcumin is a product with potential for patent application. The dissemination of this results in conferences is creating a great interest by the food industry. Thus, the PI plans to submit the idea to the intellectual property office at North Carolina A&T.

The PI will also continuously collaborate with Utah State University to improve the project's quality.

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 funded the DSC, an essential equipment for the Lipid Science. The dissemination of the results and the generation of more data in the next two years will give credibility to the Lipid Research Laboratory to improve collaborations and pursue additional funding support.

1. Manuscripts published

- Ferdaus, M. J., Blount, R.J.S., **Silva, R.C.** (2022) Assessment of Natural Waxes as Stabilizers in Peanut Butter. Foods. 11, 19, 3127.

- Airoldi, R. da Silva, T.L., Foguel, A., Rodrigues-Ract, J.N., Colleran, H.L., Ibrahim, S.A., **Silva, R.C.** (2022) Potential use of carnauba wax oleogel to replace saturated fat in ice cream. Journal of American Oils Chemists.

2. Conferences

- Ferdaus, M. J., Zauner, N., Blount, R.J.S., **Silva, R.C**. (2022 - May 02-04) Effect of rice bran and carnauba waxes on storage quality and rheology of peanut butter. Annual meeting of American Oil Chemists Society. Atlanta, GA (Poster)

- Jones, J., Payne, J., Blount, R.J.S., **Silva, R.C.** (2022- May 02-04) Effects on the physical properties of corn oil oleogels structured with different ratios of rice bran or carnauba waxes. Annual meeting of American Oil Chemists Society. Atlanta, GA (Poster)

Characterization of plant extracts as a potential surface disinfectant

Project Director
Leonard Williams
Organization
North Carolina Agricultural and Technical State University
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1023620

Characterization of plant extracts as a potential contact surface disinfectant

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

Plant based disinfectants have gained attention for their potential as norovirus inhibitors with low toxicity and side effects. The 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.

Our research team conducted a comparative study to examine the role of select commonly used disinfectants and antiviral agents isolated from hemp plant extracts on the removal of SARS-CoV-2 from food contact surfaces. Our research demonstrated that hemp can be a viable option for reducing the proliferation of SARS-CoV-2 alone and in combination with household disinfectant solutions (10% bleach or alcohol-based solutions).

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

Both the scientific community and food industry has reviewed our work as promising. However, more work is necessary (GRAS certification, Food Code, etc) before we can utilize the solution as a food contact surface disinfectant.

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

Currrently, there are limited availability of all natural disinfectants or solutions to clean and disinfect food contact services. This includes the development of GRAS solutions that can potentially be used in a food industry setting. SARS-CoV-2 is a global pandemic and will continue to be endemic in numerous communities. Thus, our studies could potentially shine some light on the behavior of SARS-CoV-2 on various food contact surfaces and role of an emerging medicinal plant (hemp) in the agriculture industry on the control of the virus.

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.

Minor changes included reducing the number of samples processed and analyzed due to the viscosity and concentrations of extracts recovered from hemp oil samples. Our analysis was inconclusive. Thus we focused a significant amount of our time on leaves and seed extracts for antiviral properties.

Our research team has trained and provided support for four graduate students and two high school apprentice. We anticipate continuing to train more students this spring and summer semesters as intern our respective laboratories.

Food safety outreach materials in collaboration with NCA&T Extension Services has been produced and shared with general public at both community and scientific symposisums. More importantly, several scientific presentations, and speaking opportunities have been generated from the interest of this project in the scientific community.

Food Safety

Project Director
Meredith Weinstein
Organization
North Carolina State University
Accession Number
7000169

Annual Result: Food Safety

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 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. The best way to prevent food contamination and ensure food safety is through education and training. NC State Extension provides educational opportunities and resources for manufacturing of food products and the retail food industry.

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 purchasing. When preserving, it is essential to employ evidence-based, research-tested strategies and methods to ensure the safety of products. Failure to adequately preserve foods can result in foodborne illness. Many families don't have the knowledge to safely preserve their food at home. The best way to prevent food contamination and ensure food safety is through education and training. NC State Extension provides a variety of opportunities to fill this educational need.

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 specialists developed resources aimed at raising awareness of and preventing food safety hazards. Research informed food-safety information was delivered to members of the food industry and consumer alike by Extension specialists and agents through Extension publications, factsheets, website portals, videos, workshops, certification trainings, demonstrations, and consultations.

- Extension specialists maintained 12 **food safety websites** viewed over 75,000 times, made 1,200 **social media posts** viewed over 1.3 million times, and created 58 food safety related **social media images**.

- Extension specialists sent out over 40 **newsletters** reaching over 800,000 readers. In addition, over 100 food safety **videos** were created and viewed 1.2 million times.

- 1,400 individuals attended **food safety training** provided by Extension agents, and an additional 4,300 individuals attended training provided by Extension specialists.

- Food safety **technical assistance** was provided to 2,600 people by Extension agents and specialists provided services to an additional 1,550 clients.

Food-insecure families took charge of their food safety practices within the home after participating in the **Expanded Food and Nutrition Education Program (EFNEP)**. Educators used Zoom, Facebook Live, Google sites, and phone communications to engage with 1,629 families and 13,029 youth, 74% of whom were enrolled in one or more food assistance programs. Eighty-six percent of EFNEP graduates improved their food safety skills.

The **NC Safe Plates** program team developed practical food safety training and educational materials for retail and consumers to impact attitudes, norms, and behaviors around food safety. In 2022, the **NC Safe Plates Food Safety Information Center** created 744 posts and 84 videos across Instagram, Facebook, TikTok, and Twitter, covering topics ranging from baked potato food safety to homemade infant formula to traveler's diarrhea. These social media posts attracted 1,217,334 views. These novel communication methods reached consumers far beyond what we would be able to accommodate in in-person classes and training. The NC Safe Plates team worked with the Wake County Public School System (WCPSS) on the **Kitchen Assessment Project**. WCPSS has 38 FCS programs in high schools across the county. Each school has at least 1 food lab, which includes 4-5 mini kitchens that students use to practice their skills. Between Fall 2021 and Spring 2022 the 38 FCS high school kitchens were assessed for safety including environmental safety, food safety, food preparation and equipment safety. Teachers were provided with a rubric for feedback and given a certificate with a letter grade to display in their kitchen. All kitchens received a letter grade 'A' to 'C' ranging from 99% to 77%. 26 food labs received a score of an 'A', 5 food labs received a score of 'B' and 3 food labs received a score of a 'C'. Extension in Columbus and Bladen Counties offered training in **Safe Plates**, Extension's evidence-based food safety program and resource for retail food professionals. A total of 50 individuals participated across both counties, and 31 received certification. Given that the average cost of a foodborne illness outbreak is $75,000, if each participating establishment prevents just one outbreak, that is a total of $2,475,000 saved. The **Safe Plates for Food Managers** course was launched online in 2021, allowing participants to attend 12 hours of instruction to pass a certified food protection manager exam. Through online training and collaboration with local Extension Agents, 329 participants received 3,948 contact hours to achieve this certification. Through a partnership with the NC Department of Public Instruction, Extension continued to support school foodservice handlers, managers, and child nutrition directors across NC. As a result of needs assessments conducted in previous years, two bonus modules for **Safe Plates for School Nutrition** staff were created to expand the course's depth on allergens and produce, 2 additional programs were launched to address emergency readiness and response, including maintaining food safety while children are sheltering at school due to natural disasters and responding to food recalls and foodborne illness outbreaks. Alexander County Extension offered **food safety training** to the local school system, providing two-day training on Safe Plates as well as the training required to become a Certified Food Protection Manager, a role critical to keeping school systems in compliance with the NC Food Code. The training was provided to 17 nutrition staff from the Alexander County School System, including 10 modules on receiving, storing, cooking, and cooling food as well as standards for health, cleaning, and pest and allergen management. Thanks to the hands-on training and real-world case studies provided with each module, all 17 participants passed the exam with an 80% or higher, becoming Certified Food Protection Managers. In addition, all of the participants stated that the Safe Plates training helped them develop a deeper understanding of the "why" behind food safety procedures. Many individuals reported that the interactions with the instructors and the case studies helped them pass the exam. In Rockingham County, Extension partnered with the Safe Plates team to provide a series of **virtual food safety classes**, serving a total of 43 participants, the majority of whom were international participants from Canada. The program was presented weekly at lunch time, and the recordings were sent to those who were unable to attend the live session. These classes offered a unique opportunity to discuss differences in food safety systems between the US and Canada and ensured that the impact of Extension's food safety training materials spread across US borders. **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 to build more resilient school food services.**

As a result of attending Extension programs over **22,500 participants** increased their knowledge of safe home food handling, preservation, or preparation practices and **2,750 food handlers** increased their knowledge and skills in safe food handling practices.

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

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. This program provided stakeholders with daily support via phone and virtual meetings, and provided consultations, education, and resources necessary for the success of their businesses. In 2022, EI4F provided 899 processing recommendation letters and 334 nutritional labels. **NC State Extension's extensive partnerships with agriculture, business, and industry resulted in the development of safe new food products.**

Both the implementation of the FDA's New Era of Smarter Food Safety blueprint and COVID-19 challenges have introduced **regulatory changes**, and regulatory staff need help educating food industry professionals in these changes. Extension partnered with STOP Foodborne Illness and Cultivate Food Safety to create a 4-hour virtual course to educate regulatory professionals on food safety culture. This course helped 1,001 FDA staff increase their knowledge of how to promote an effective, compliant food safety culture. **NC State Extension enhanced food safety through programming aimed at preventing food safety hazards during the food manufacturing process and fostering a culture of compliance and accountability.**

To promote food safety and sustainable economic development for NC, Extension partnered with NC State researchers to provided **critical technical assistance and education** across 3 major areas: scientific research, facilities and resources, and support for food industry businesses. In 2022, Extension developed and delivered an **alternative protein processing workshop** for 27 people and **food labeling and value-added food production workshops** for 187 people. Workshop participants reported being 2.5 times more confident about processing alternative proteins, 3 times more knowledgeable in conducting food safety programs, and 2 times more confident in following food labeling regulations. Through **direct consultation** with food companies, Extension also assisted with the development of a mobile processing facility, the expansion of a hot sauce producer in South Carolina, and the refinement of product concepts and a food production prototype for Cosmic Eats, Inc., a company that is working to deliver high-nutrition food products in a manner that is resilient against supply chain disruptions and other food security risks.

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 control critical points in food handling to prevent food safety problems and reduce the reliance on end-product inspection and testing. This course allows local environmental health professionals to gain confidence in recognizing and approving specialized processes in a retail food environment while learning to build plans that are in compliance with regulations and sustainable for their businesses. The Retail HACCP course for regulators and restaurant operators was transitioned online in late 2020. In 2022, 116 regulators and operators from across the US received 1,392 contact hours of instruction in retail HACCP.

Seafood HACCP plans are FDA-mandated for seafood processors and if a seafood processor does not have an HACCP-certified individual on staff, they cannot legally operate. In 2022, Extension provided 7 seafood industry personnel with training and certification in Seafood HACCP and assisted in writing or reviewing 20 HACCP plans for 8 companies. Additionally, 34 individuals were provided with information on obtaining HACCP training or implementing HACCP plans. **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 processors' knowledge of BMPs that reduce the likelihood of foodborne illness.**

Along with the need for HACCP-trained individuals, the seafood industry requires the development and innovation of new products and processes, testing services, and technical advice. The Seafood Lab has been an essential resource for seafood processors, providing **shelf life and quality testing** for 2 products and **cooking process validation** for 1 product. The Seafood Lab team also referred 7 people to the Entrepreneur Initiative for Food program for additional services, visited 6 seafood processing plants to assist with **preparation for FDA inspections**, provided **authority letters** to 8 companies, and provided **technical assistance and advice** regarding seafood science and technology to 100 individuals and companies through phone calls, meetings, and emails. As a result of this support for product testing and process validations, multiple NC food companies can now prepare products according to required safety specifications, and they have precise information about their products' quality and shelf life to make good decisions affecting consumer safety.

In 2022, Cooperative Extension continued efforts to strengthen aquaculture production by **delivering improved technology and best practices**. As part of Extension's Smart Aquaculture program, an app that predicts weather-related runoff impacting the safety of oyster crops was upgraded to provide 3–5 days of notice to producers so they have time to harvest or take other actions to reduce losses and enhance the value of their crops. A mid-sized oyster farmer who harvests approximately 20,000 oysters at an optimal time to secure optimal pricing could gain approximately $6,000 in income by using this app, all while avoiding potentially severe health impacts to consumers. Extension researchers are also in the process of developing best practices for cultivating finfish larvae in the recirculating aquaculture systems that are used in industry to keep fish tanks clean. The best practices have nearly been completely developed under lab conditions, and upscaling for commercial

development is ongoing. These best practices have the potential to improve larval survival by 30% or more. **Extension's food safety and processing programs provide education, one-on-one consultations, safety plans, and product development recommendations that enhance the safety, innovation, and profitability of NC food businesses.**

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

The recent economic downturn and growing interest in local and organic foods has brought renewed interest to home food preservation. However, food preservation is a science-based practice, and testing the safety of recipes can only be conducted in a lab with special equipment and trained food scientists. Surveys conducted by the National Center for Home Food Preservation revealed a high percentage of home food processors use practices that put them at high risk for food-borne illness and/or economic loss due to spoilage. Factors such as a younger demographic and outdated and unreliable home canning practices lead to unsafe situations. Low and high acid foods are at risk for spoilage if not canned properly and Botulism is a risk for low acid foods that carries a 10-35% mortality rate for those infected.

Extension helped individuals and families increase their knowledge of food safety through a variety of educational programs, including hands-on workshops. **Home food preservation classes** were offered to home cooks through the Haywood County extension center. 69 participants were trained in safe home food preservation. Participants and their families benefit from the reduced risk of foodborne illness and food spoilage. Overall, an economic savings comes from money NOT spent on medical bills and spoiled food.

To help residents reduce their food waste and grocery bills while preserving their health, Extension in Beaufort County offered hands-on home food preservation training workshops in May and June of 2022, and libraries, community centers, and local community partners helped market the classes. Through these workshops, 97 participants learned how to prepare pickles, jams, and jellies, and they gained knowledge of pressure canning for low-acid foods, boiling water canning for high-acid foods, dehydration, and freezing methods of preservation. As a result of these workshops, 100% of participants increased their knowledge of best storage practices for canning, freezing, and dehydrating foods, 95% increased their knowledge of approved equipment for home food preservation, and 85% increased their knowledge of preparation and processing for pickles, jams, and jellies. Many participants expressed appreciation for the hands-on instruction method and practical demonstrations, and 100% indicated that the information provided was informative and easy to understand.

In Hyde County, Extension offered hands-on, in-person produce preservation classes throughout the year, teaching best practices through canning, pickling, freezing, and dehydration and reaching 71 direct contacts, 27 of whom were youth participants. In addition to the in-person classes, Hyde County Extension offered a kindergarten field trip to a local strawberry farm to ensure a memorable experience for the youngest participants. Pre- and post-evaluations provided by 63 participants reveal that 95% increased their knowledge of food preservation, where to find tested recipes, and pathogens of concern; 100% increased their knowledge of safe thawing methods and how to properly store and package home canned foods; and 87% increased their knowledge of approved equipment for home food preservation. Many participants reported feeling much more confident trying the methods at home thanks to the hands-on instruction.

To provide specialized support to immigrant families, Richmond County Extension partnered with Cornerstone Church to provide bilingual instruction in food preservation, offering handouts in both English and Spanish outlining recipes, easy-to-follow food safety notes, a condensed history of food preservation, and the differences between all the varieties of sweet spreads. The class was conducted in English and Spanish, and all participants gained hands-on experience from start to finish. Thanks to this class, 2 participants have begun collaborating to preserve strawberry jam for family and friends, and they are preparing to take more food preservation classes through Extension so that they can continue sharing what they've learned with other Spanish-speaking families in their community. One hundred percent of the participants indicated that they gained knowledge of safety practices for home food preservation, and many shared that they grew up watching their mothers and grandmothers use practices that would not be considered safe today.

According to the US EPA, one-third of all food in the United States goes uneaten with 20.3 tons finding its way to landfills or combustion facilities. "Preventing food from going to waste is one of the easiest and most powerful actions you can take to save money and lower your climate change footprint by reducing greenhouse gas (GHG) emissions and conserving natural resources." In addition, by increasing consumer knowledge of safe food preparation and preservation practices NC State Extension is improving consumer health and reducing food-related illness. **NC State Extension is a reliable educational resource to teach food safety to consumers. Most people don't realize how much food they throw away every day– from uneaten leftovers to spoiled produce to parts of fruits and vegetables that could be eaten or repurposed.**

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 2022 to facilitate the use and transfer of new research-based knowledge:

- Boiling Water Can-Along
- Food Labeling Facts and Myths 2.0
- Food Safety? Food Quality? What's the Difference?
- Immersive Food Safety Training for Farmers Markets & Small Farms
- Overview of Home Processing Risks & Requirements
- Produce Safety Alliance Training
- Safe Plates for Farmers' Markets
- Safe Plates Home Food Preservation
- Safe Plates Retail Programs Training

The following **Factsheets and Peer Reviewed Extension Publications** were developed by Extension Specialists for dissemination of research-based information to Extension agents, growers, and other stakeholders.

Basic Food Microbiology

Choosing and Using a Copacker

Considerations for Developing a HACCP Plan for Acidified Foods

Developing a Recall Plan

Extended Shelf-Life Refrigerated Foods

FDA Food Processing Facility Registration

Listeria

Refrigerated Foods: Some Rules for Processing

Scheduled Processes

The Questions on Salvaging Flooded Crops

Vinegar Making

Who Will Regulate My Food Business?

Extension specialists contributed to solving regional and national issues through **multi-state collaborative Extension efforts**. Some multi-state programs NC State Extension participated in include:

- Food Safety Extension Network. The goal is to establish a consortium of institutions from the southern region to synergistically advance the science of consumer and retail/food service food safety and share expertise, training, and developed materials across the Land-grant system.

- Co-leading a multi-state Food Safety Extension Network effort with faculty at UGA to better share food safety resources and programming related to home food preservation, cottage foods and home-based businesses, and retail food safety.

- Immersive food safety training for farmers grant collaboration with Virginia Tech and RTI International.

- Food CoVNET collaboration with faculty at UF, UNL, and Rutgers.

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 country. 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. To reduce instances of foodborne illness, NC State Extension developed resources and provided training on food preparation and food safety. Extension provided NC Safe Plates 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 specialists are working to establish a Food Safety Extension Network of institutions across the southeast to synergistically advance the science of consumer and retail/food service food safety and share expertise, training, and materials across the Land-grant system. Collaborators include institutions from the southern region.

As a result of Extension's efforts, 20,693 participants increased their knowledge of how to prepare foods, including home food preservation techniques and 22,632 participants increased their knowledge of safe home food handling, preservation, or preparation practices. 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.

delete

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

x

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.

x

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

xx

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

x

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.

x

Nutrition & Health

Project Director
Meredith Weinstein
Organization
North Carolina State University
Accession Number
7000170

Annual Result: Nutrition & Health

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

Obesity poses one of the most serious public health challenges of the 21st century. In 2020 North Carolina 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, 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. In addition, over 1.2 million people in North Carolina are facing hunger, among them nearly 400,000 are children. Food insecurity significantly increases the risk of developing chronic diseases such as obesity, heart disease, Type 2 diabetes, and high blood pressure. It also leads to poorer mental health, delayed development in children and can negatively impact children's academic performance.

To help North Carolina reduce chronic disease risk and food insecurity, NC State Extension has promoted policies, systems, environments, and direct 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.

- Over 8,000 **adults** attended **nutrition-related workshops**, and 4,500 adults attended **health and wellness workshops** provided by Extension Family and Consumer Science (FCS) agents. 4,700 adults attended **workshops related to cooking**, and 2,300 attended **food preservation workshops** provided by Extension FCS agents.

- 18,600 **youth** participated in **nutrition, cooking, and health** school enrichment programs, camps, clubs, and outreach activities.

- 1,800 hours of service were donated by **Extension Master Food Volunteers**, valued at $54,000; and 8,700 hours of service were donated by EFNEP volunteers, valued at over $260,000.

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. In 2022, Steps to Health reached 3,166 participants (2,795 youth and 371 adults) through 170 **direct education programs**. Steps to Health promoted **policy, system, and environmental (PSE)** change initiatives across 16 schools and 31 community sites, supporting change strategies that impacted 13,000 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 517,070 impressions on **social media** and 3,804,985 impressions through social marketing implementation of **digital advertisements** and a **text message campaign**. **Educational video shorts** featuring animated host avatars and based on Steps to Health's chronic disease prevention program **Take Control** were viewed 1,872 times. Across all adult programs, 57% of participants reported improving healthy eating behaviors, 56% reported eating more fruit, 51% reported eating more whole grains, and 46% reported improving their physical activity.

Steps to Health's **Color Me Healthy** program is a 9-session sensory-rich direct education program designed to improve fruit and vegetable intake and increase physical activity among 4 and 5 year old children in child care and preschool settings. It uses color, music, dance, and imaginary play to provide **opportunities for physical** activity and to **teach children about fruits and vegetables**. In Macon County, the Color Me Healthy program was delivered to children, using color, music, taste tastes, and other memorable sensory experiences to encourage them to build healthy habits. At least 387 educational contacts were made, and parents observed improvement in children's willingness to try fruits and vegetables and increase physical activity. In Lee County, Color Me Healthy was taught at 4 sites, reaching sixty-seven 4 and 5-year-olds. Lee County followed this program up with a **Farm to ECE** program, including the **installation of vegetable garden beds**, to continue the children's engagement in learning about and eating healthy foods.

EFNEP, the Expanded Food and Nutrition Education Program, offers free nutrition classes to help families and youth cook healthy meals at home, be more active, save money on food costs, and handle food safely. In 2022, EFNEP programs across 40 counties served 1,629 families and 13,029 youth, 74% of whom were enrolled in one or more food assistance programs.

In Randolph County, Cooperative Extension was asked by a local TV channel (CW) to provide a **cooking demonstration for a morning show** called "Local Vibe." This segment included nutrition and cooking education shared by the local Family Consumer Sciences Agent, and it reached an estimated TV audience of 716,510, with segment videos on YouTube being viewed by 40–400 individuals and shows posted on social media reaching an average of 400 individuals. Viewers shared that they have made several of the recipes, and the videos have supported a 60.7% increase in engagement on Extension's Facebook platform in only a few months. **Through NC State Extension cooking programs, clientele used learned strategies, skills, and resources to reduce the risk of chronic disease and illness, and through local media outreach, residents have gained awareness of the resources and assistance that Extension can provide.**

As a result of NC State Extension programs, **60,000 adults and 75,000 youth** increased their fruit and vegetable consumption, **6,000 adults and 20,000 youth** increased their physical activity, **4,000 adults** consumed less sugar, and **4,000 adults** consumed less sodium in their diet.

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

To combat obesity rates and food insecurity in vulnerable local populations, NC State Extension in Pitt County created and implemented the **"Dinner in a SNAP"** curriculum, a 6-week program designed to provide nutrition, food safety, budgeting, and physical fitness education to limited resource families. Nine participants received cooking equipment, educational incentives, thermometers, and ingredients to make the recipes. Thanks to the program, the women with young children who participated all learned to read and understand food labels and make healthier choices for their families. They also learned new, healthier alternatives when cooking recipes, and they have started to plan their meals using MyPlate as a guide. The "Dinner in a SNAP" program is being expanded into 3 additional counties.

Data from school height and weight checks showed that over 85% of students in one Richmond County elementary school were overweight or obese. This was especially concerning in a county where over 64% of youth live in poor or low-income homes. The **Steps to Health Program** was delivered to all 3rd grade students at this elementary school, and healthy snacks were provided along with all the curriculum, books, and materials needed to complete the classes. Each lesson contained a physical component, so the students were very active during the lessons. Recipes and nutrition guidance sheets were sent home to parents in both English and Spanish to reinforce what the students were learning in class at home. 85% of participating youth improved their fruit and vegetable consumption, 100% of youth increased their water intake, 100% of youth are more active as a result of the program, and 90% of youth are willing to try new foods. Across all Steps to Health youth programs statewide, 37% of participants improved their fruit consumption, 42% of 2nd and 3rd graders used nutrition

facts labels to make food choices, and 30% of 2nd and 3rd graders drank less soda. **Through Steps to Health, a comprehensive approach to impact the health and nutrition of limited-resource NC residents, Extension delivered education to food-insecure families and youth while promoting systematic community changes to support healthy living.**

EFNEP partnered with the Clark Street Boys & Girls club in Vance County for students to learn healthy eating habits. At this location, 49 students participated in the 2-week, 6-session **Show Me Nutrition** program. Over the course of 9 hours of programming, participants learned healthy recipes for an appetizer, entrée, and dessert, utilizing each of the food groups from MyPlate. After completing the lessons, 64% of the youth increased the number of days they were physically active for at least an hour, 57% made healthier food choices while eating out, 40% improved reading of nutrition facts labels, and 35% tasted new foods more often.

Improving diet, increasing exercise, and promoting healthy lifestyles are top health concerns for Franklin County. Physical activity is important because it reduces stress and prevents disease and obesity. This academic school year, 381 youth participating in **EFNEP** classes set weekly goals and challenged themselves to **live healthier lifestyles**. Weekly goals they achieved included cleaning their rooms, completing 60 minutes of daily physical activity, completing household chores, and increasing fruit and vegetables consumption. In addition, EFNEP encouraged youth to complete the following activities as a family: cleaning household indoors and outdoors, walking the dog, riding a bike, walking to the mailbox, taking brain breaks in between TV commercials, raking the lawn, mopping the floors, vacuuming, and folding clothes. As a result of EFNEP programming, 381 youth were motivated to reach their weekly health goals, 352 youth increased their fruit and vegetable consumption, and 381 youth improved their physical activity. Youth also reported that maintaining a clean space helped them improve their attitude toward learning each day. Statewide ninety-seven percent of EFNEP participants improved dietary intake, 53% practice daily physical activity, 96% practice better food resource management, and 86% have improved their food safety habits. **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.**

In Chowan County, 30 percent of adults are obese, compared to the national benchmark of 25 percent. Contributing to this epidemic are poor nutrition and physical inactivity. Sixty-six percent of residents in Eastern NC consume fast food each week. More consume sugar-sweetened beverages daily (60%) than the recommended fruits and vegetables (18%). NC Cooperative Extension was asked to partner with Albemarle Regional Health Services (ARHS) on the Albemarle Get Fit program and offer healthy cooking lessons using the **Med Instead of Meds** Extension curriculum. As a result, participants were educated on nutritious foods and how to prepare healthy recipes in the Med way in virtual "Cook Along" classes. Participants received a food kit that included all needed ingredients, and they logged on and cooked along with instructors. Participants were also encouraged to set health goals (weight loss, increase physical activity, healthier eating). As a result of these classes, participants learned hands-on healthy cooking techniques at home. Participants indicated healthy eating practices and lifestyle changes were made to reduce the risks of chronic disease. With these lifestyle changes and improved health, it is estimated that each participant could save an average of $100 per physician visit. **Through NC State Extension nutrition programs, clientele used learned strategies, skills, and resources to reduce the risk of chronic disease and illness.**

Communities that create spaces for physical activity have healthier people with decreased risks of obesity, heart disease, and other chronic conditions that increase morbidity and mortality. Rockingham County's adult obesity rate (36%) is higher than the State rate of 31%. **A fitness class**, called PoundFit was presented over the course of 3 weeks to staff at Rockingham County Community College. The staff there typically have sedentary jobs that require very little physical activity, and their wellness director asked Extension to present some wellness programming for their staff. At the conclusion of the class, a client expressed that she used to be very avoidant of physical activity because she was intimidated and found it unappealing and that she now truly enjoys exercise and has committed to purchasing equipment to continue to participate in this activity as well as seeking out new ways to be physically active.

To help residents combat the dangers of a sedentary lifestyle, Extension Agents in Edgecombe and Nash Counties worked together to hold a **4-week walking challenge** for 118 participants. Each week had a special theme, and participants received a newsletter with tips on healthy eating, increasing physical activity, and fun facts about Edgecombe and Nash Counties. Participants logged a total of 10,416,855 steps, or 4,340 miles with an average participant step count of 226,454. Many of the walkers expressed that walking was a great way to start being more physically active. One participant shared that she lost 15 pounds during the walking challenge, and she continues to walk daily. Many of the participants formed walking groups and continue to help others increase their physical activity. **Through NC State physical fitness programs, residents have gained the skills they need to live more active, fulfilling lives and the confidence to share what they've learned with others in their communities.**

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

Despite widely accepted documentation that consumption of fruits and vegetables can improve health outcomes, many Americans are not eating the quantity of these foods that would bring on advantageous changes. In particular, those who have low food security are less likely to eat fruits and vegetables regularly. In North Carolina, food insecurity affects 1 in 7 people. People living with food insecurity also experience higher rates of diet-related chronic illness. To address the double burden of hunger and poor health, Extension as well as healthcare providers are looking for ways to connect their clients and patients with accessible and healthy food. In response, **PhytoRx**, a **produce prescription program** that aims to connect providers, patients/clients, local food pantries/retailers and FCS agents, was created by Extension at the Plants for Human Health Institute. PhytoRx fills a knowledge deficit by training providers in how phytochemicals in specific fruits and vegetables affect patient health relative to particular diagnoses which allows the development of more comprehensive treatment plans. This collaborative program connects their patients with the education and research offered by NC Cooperative Extension.

The aim of the PhytoRx pilot program was to "prescribe" fruits and vegetables to a food insecure population, in a way that encouraged higher consumption, demonstrated ease of incorporation and motivated continued purchases for health benefit, not just sustenance or taste satisfaction. In addition to directing patients to fresh produce, the program included nutrition and health coaching, instruction on food preservation and preparation, and incorporation of locally grown crops. All the participants enrolled in this program reported trying new fruits and vegetables as well as increasing their daily and weekly consumption of produce. They also reported shifts in their view of produce and the potential benefits to their overall health. In addition, the barrier of transportation was removed by a partnership with United Way of Iredell County and the Drive United program. This enabled the clients to receive their weekly produce prescriptions via DoorDash delivery. This was a great way to increase food equity among participants and those who typically would never have the opportunity to have food delivered to their homes.

The framework and design of this program is in place and can be replicated throughout NC and beyond. This program is exclusive in its application to underserved communities. All healthcare providers can benefit from including PhytoRx into their practice. **In addition to increasing community knowledge of affordable produce options, this program provides evidence-based education to healthcare providers about how specific phytochemicals can improve a variety of chronic illnesses. This offers another tool in the medicine bag—one that doesn't come in a bottle but can be found in the kitchen.**

Food insecurity is a problem facing families across the United States in both urban and rural communities alike. Seventy-two billion pounds of good food goes to waste each year in America, while at the same time, 34 million people face hunger. In Chowan County, 1 in 5 households are food insecure, and many families must pick between food and other household necessities such as gas, transportation, and medicine. The commercial horticulture Agent, in partnership with Chowan Farms, helped harvest the potato breeding trial in Chowan County. After harvest, the potatoes were taken to the **Vernon James Center** to be graded and recorded for research. Seeing the field still full of potatoes, the agent-organized a potato gleaning project to benefit the local community. The agent with the grower's permission organized Extension employees and master gardener volunteers to glean the remaining 12 rows of potatoes. It was a team effort to dig the potatoes and get them bagged up so that the food pantry could properly weigh and store them. The Agent and her team were able to donate over 600 pounds of potatoes to the Edenton-Chowan Food Pantry in Chowan County and the Open Door Food Pantry in Perquimans County. The food pantry often gets non-perishable food items but rarely gets fresh food. Averaging at 600 pounds of potatoes at the local grocery store price of $1.18lb, this project was valued as a $706.80 donation to the food pantries.

Following the initial harvest and crop assessment of blueberries at the NCSU Horticultural Crops Research Station in Castle Hayne, the remaining blueberries can go to waste in the field yet many people face food insecurity and lack access to fresh, healthy produce. Extension staff from Brunswick, Pender, New Hanover, and Bladen Counties and 104 volunteers gathered at the research station to pick blueberries by hand. The volunteers were educated on the variety of blueberries and types of research conducted at the research station and learned about the importance of access to fresh produce for life long health and the role that the Food Bank plays in helping to deliver food to those that are in need. In total over the two gleaning days, 770 pounds of blueberries were harvested. These blueberries were given to the Food Bank of Southeast and Central NC in Wilmington where they were distributed to partner organizations that help our food insecure neighbors.

Rutherford County Cooperative Extension's Farm-to-Pantry Project helped food insecure families in transitional living situations. These families received fresh produce and meats, but they had no kitchens to prepare their food. To address this problem, Extension secured funds to purchase over 25 kitchen kits. These "kitchens in a box" included a slow cooker, electric skillet, cooking and food prep utensils, short-term cold storage solutions, dishwashing supplies, staple ingredients, and recipes. Extension Master Food Volunteers donated food, assembled kits, tested recipes, and conducted cooking demonstrations, ensuring that 22 families (47 adults and 35 children) learned to prepare healthy, low-cost meals at home. Preliminary survey results show daily or weekly use of the kits. **NC State Extension used innovative kitchen kits to deliver nutrition education and tools to families and community members and bring about behavioral changes focused on healthy eating patterns to improve overall health.**

Extension in Nash County combatted food insecurity for seniors by partnering with the Upper Coastal Plain Council of Governments to deliver 250 grocery boxes to Nash, Edgecombe, Wilson, Halifax, and Northampton Counties. The boxes included vegetables, grains, and protein products from local farmers and farmers market vendors. To date, over 14,228 produce boxes have been distributed to senior citizens in need through this program.

14.6% of children in Currituck County reside in food insecure households. To combat this problem, Currituck County Extension partnered with the Food Bank of the Albemarle, the local school system, and other local organizations to administer a weekend backpack feeding program during the school year. Extension staff and volunteers raised money through private donations, corporate sponsorships, and grants and handled the logistics of ordering food, maintaining inventory, and coordinating weekly deliveries. As a result of this vast collaboration, 21,210 meals were distributed to 110 of the highest need elementary students in Currituck County throughout 2022. **Extension has helped meet the nutritional needs of food insecure members of the community through facilitation of food donations while building robust local partnerships to address the growing problem of food insecurity. This is just one way Extension is addressing food insecurity in vulnerable populations and creating models for other communities working to overcome barriers to a healthy lifestyle.**

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 2022 to facilitate the use and transfer of new research-based knowledge:

- Development of Sweet Potato Nutrition Bar
- EFNEP-Snap-ED Training
- Harvest Health: A Produce Prescription Program
- Let's Get Physically Active with Programming
- Not Just FCS: Making Impacts with Steps to Health
- PhytoRx and Fruit and Veggie Prescription Programs
- Steps to Health Agent Training
- Steps to Health Community-Based Programming
- Steps to Health School-Based Programs

Extension specialists contributed to solving regional and national issues through **multi-state collaborative Extension efforts**. Some multi-state programs NC State Extension participated in include:

- Policy, Systems, and Environmental Change collaborative group with other Extension Health Specialists to discuss how to better implement PSE changes through extension across the U.S.

- Southern Region Health Specialists network.
- Faithful Families program has been implemented in 21 states across the U.S. In 2022, 7 new national facilitators were trained to use the program.
- Extension Health Leadership Committee.
- Appalachian Health Conference

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 Extension programs, over 8,000 adults attended nutrition-related workshops, and 4,500 adults attended health and wellness workshops provided by Extension Family and Consumer Science (FCS) agents. 4,700 adults attended workshops related to cooking, and 2,300 attended food preservation workshops provided by Extension FCS agents. In addition, 18,600 youth participated in nutrition, cooking, and health school enrichment programs, camps, clubs, and outreach activities. Extension Master Food Volunteers donated 1,800 hours of service valued at $54,000; and EFNEP volunteers donated 8,700 hours of service valued at over $260,000.

delete

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

delete

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.

x

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

x

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

x

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.

x

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.

In this study, 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 and fish samples were deep-fried in either canola oil or oleogels. Oleogel-fried samples had significantly lowered the fat contents than canola oil-fried samples but oleogelation did not improve the oxidative stability of the fried samples. However, the use of an edible coating with thyme essential oil offered better oxidative stability in the fried samples ($P<0.05$) for up to 4 days. Citrus peel fiber (CPF) at 0, 0.5, and 1.5% was also added to the batter to improve the quality and reduce fat uptake. Fat uptake was reduced to 43.27% and 50.83% in 0.5%CPF and 1.5%CPF samples, respectively ($P<0.05$). Ash content, pH, and color values were not altered.

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 factor journals and present their results at IFT annual meeting which was held in July 2022 and won second place in the graduate 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 of this project have been published in high-impact factor journals indexed in Food Science. We also shared our findings with the public and farmers during the small farm field day which was held in the summer of 2022 at NC A&T farm. We will work to complete all the objectives of the project by the termination date of the project which is September 2023.

Peer-reviewed publications

1. Ardekanizadeh A.H., **Tahergroabi R.**, Hosseini S.V. Hosseinabadi Z., Feas Sanchez X. (2022) Assessment of relationships between nutritional quality indices of Beluga sturgeon (*Huso huso*) fillets and frying with different vegetable oils. *Journal of Agricultural and Crop Research.* 10(6), 105-112.

2. Adegoke, S. C., Adrah, K., Nowlin, K., & ***Tahergorabi, R.** (2022). Microstructural and physicochemical changes of coated and frozen fried chicken. *Journal of Food Processing and Preservation*, 46 (9), e16822.

Conference presentations

1. Mahmud N, Islam J, Adegoke S, Adrah K, & **Tahergorabi R.** (2022). Effect of oleogel and an edible coating on quality of deep-fried chicken breast. NCAFCS Annual Conference, Kitty Hawk, NC.

2. Mahmud N, Kornegay Z, &**Tahergorabi R**. (2022). A study on the effect of citrus peel fiber in batter on oleogel-fried chicken. IFT Annual Meetings, Chicago, IL.

3. Islam J, Gaddis A, & **Tahergorabi R.** (2022). Effect of citrus fiber addition to the batter on physicochemical properties of deep-fried surimi fish balls. IFT Annual Meetings, Chicago, IL.

4. Islam J, Gaddis A, & **Tahergorabi R.** (2022). Effect of citrus peel fiber addition to batter on physicochemical properties of deep-fried surimi fish balls. Small Farm Field Day. NC A&T SU.

5. Islam J, & **Tahergorabi R.** (2022). potential application of oleogel and citrus peel fiber in fat uptake reduction of deep-fried surimi products: an overview. National Conference on Next Generation Sustainable Technologies for Small Scale Producers. NC A&TeSU.

6. Mahmud N, & **Tahergorabi R**. (2022). Modification of frying oil and batter for fat uptake reduction in deep-fried chicken products: an overview. National Conference on Next Generation Sustainable Technologies for Small Scale Producers. NC A&T SU.

7. Joinul Islam won second place in the oral presentation of the IFT student competition.

8. Joinul Islam and Niaz Mahmud were selected as outstanding graduate students among all the students in the College of Agriculture and Environmental Sciences at NC A&TeSU.

Advanced Thermal and Continuous Microwave Processing of Foods and Biomaterials

Project Director
Josip Simunovic
Organization
North Carolina State University
Accession Number
1020669

Annual Result: Advanced Thermal and Continuous Microwave Processing of Foods and Biomaterials

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

During over 25 years of intensive laboratory, pilot plant and commercial research our lab teams have developed several novel, advanced methods for food, beverage and biomaterial processing and packaging utilizing continuous flow microwave heating, pasteurization and sterilization.

The need for advanced thermal food processing methods and technologies evolved from the long recognized shortcomings of so called conventional thermal processing. Conventional processing, in order to deliver the minimum treatment required to achieve safety and shelf stability of the least processed element of food material, imparts severe and excessive flavor, color and specifically nutrient degradation through over-processing of all other treated elements of the food. Therefore, with the exception of the so called "cold spot" there are unnecessary losses of quality and nutrients in all other elements of the processed food. This is particularly well exemplified by the poor quality and therefore continuing market segment losses of canned foods in favor of refrigerated and frozen food categories.

The issue with refrigerated and frozen food products is the continued, unnecessary energy consumption throughout transport, storage and distribution as well as the risk of spoilage and the related potential for health hazard developments if the maintenance of low temperatures is interrupted.

We have addressed the emerging need for an advanced novel technology for processing to achieve high quality and concurrent shelf stability at ambient temperatures by developing a new technology based on exposure to microwave heating under the continuous flow conditions, followed by packaging into flexible (aseptic) packaging. These package format sizes range from individual serving sizes of few ounces to large drums (200 to 500 lb), and totes of up to 1 metric ton per package used as ingredients for further processed product. In the process, several processing facilities have been built in the U.S. and abroad and are currently used to process several hundred different products and ingredients, primarily based on vegetable and fruit purees, which have been previously difficult to preserve due to excessive quality and nutrient degradation and/or the risk of spoilage and health hazards if processed using gentler methods resulting in perishable products needing refrigerated or frozen storage. In addition to this contribution to the reduction of greenhouse gas generation, our technologies and production facilities are also using the emission-free electric technologies for processing and preservation. We are therefore having a positive impact both in the elimination of emissions as well as the further electrification of our industries and the communities they serve.

Continued avoidance of the need for new, superior processing technologies would result in further increase in both visible and invisible food waste and nutrient losses and excessive and unnecessary energy consumption for refrigerated and frozen storage and distribution of products which can be processed and preserved to a high degree of quality and nutrient maintenance and long term shelf stability and storage at ambient temperature levels.

During the last reporting year two such facilities have been constructed and put into operation – after the original FirstWave Innovations facility in Raleigh NC - another one in North Carolina - FirstWave Innovations in Nash County (a division of SinnovaTek in Raleigh, NC, USA) and another one near Nairobi, the capital of Kenya. The facility in Kenya is the first facility of its kind on the African continent, both by the implemented advanced thermal technology (continuous flow microwave sterilization and aseptic packaging) and the types of products and ingredients produced (shelf stable fruit - mango and vegetable - sweetpotato purees) to be used in baby and infant foods, as well to replace up ro 40**%** of the imported wheat in local bakery items and achieve a multiple purpose: increase the income base and sustainability of the local small holder farmers, reduce dependence on imported wheat at the time of global grain market disruption caused by the Russian agression in Ukraine, and adressing the primary cause of childhood blindness in sub-Saharan Africa - nutrient defficiency in Vitamin A (sweetpotato is particularly rich in beta-Carotene, provitamin A).

In addition to maximizing the preservation of sensitive flavors and nutrients and extending the shelf life without the need for refrigeration to 12-18 months at ambient temperatures, the new technology has been proven as exceptionally successful in minimizing or eliminating food waste under a variety of post-harvest, pre-processing and post-processing conditions (the rate of food waste addressed has been >40**%** in the U.S. for sweet potatoes and >60**%** for mangoes in Kenya and other African countries). Food loss and food waste are a global food security related issue, and with properly minimizing them, all participants in the food production and distribution systems would benefit, from small holder farmers and growers, to processors to the consuming public.

Our technology therefore addresses both visible (physical) and invisible wastes and losses (chemical and thermal due to outdated excessive processing) while at the same time reducing energy waste and greenhouse gas emissions.

An additional benefit of our rapid, uniform and volumetric heating methodology has been the minimization of both in-process product volumes and the time spent in processing – these two advantages have been combined to achieve the physical minimization of product lines and maximization of the related throughputs, both for stationary and mobile processing systems. Our active installations have therefore become the very efficient catalysts for new product development and product innovations due to the small processing capacities required for full commercialization, Just in the first year of its operation, the MW processing facility in Raleigh has been instrumental in commercialization of over70 new food 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.

In addition to maximizing the preservation of sensitive flavors and nutrients and extending the shelf life without the need for refrigeration to 12-18 months at ambient temperatures, the new technology has been proven as exceptionally successful in minimizing or eliminating food waste under a variety of post-harvest, pre-processing and post-processing conditions (the rate of food waste addressed has been >40**%** in the U.S. for sweet potatoes and >60**%** for mangoes in Kenya and other African countries). Food loss and food waste are a global food security related issue, and with properly minimizing them, all participants in the food production and distribution systems would benefit, from small holder farmers and growers, to processors to the consuming public.

Over more than 20 years of intensive research, development and commercialization, inventors, developers and new business founders from our teams at the NC State University Department of Food, Bioprocessing and Nutrition Sciences have invented, developed and commercialized 4 new generations of continuous flow microwave processing technologies for preservation of foods, beverages and biomaterials. We have also invented, developed and commercialized the instrumentation, sensing devices and protocols for validation of safety of products produced using our novel advanced technologies, other advanced processing technologies (ohmic/electrical resistance heating, electrical induction heating, radio frequency heating) as well conventional heat exchanger technologies. 20 United States and over 50 International patents have been granted and implemented in industrial production.

12 new businesses have been founded and are commercially active based on the technologies licensed from NC State University we have developed and commercialized, also resulting in several production facilities (over 10) and many R&D laboratory, pilot plant and innovation development center installations in the U.S. and abroad.

We have organized and presented numerous short courses, training sessions, demonstrations and presentations at NC State University, other open access venues as well as confidential, limited access events at many major consumer goods companies and supplier in the U.S. and abroad.

We have provided the education and training for numerous students and professionals, currently active in the food processing industries throughout the world, both in further implementation of our technologies as well as optimization of existing systems and operations, development of new products and maximization of their nutritional value, reduction of greenhouse gas emissions and increasing profitability of secondary and upcycled products throughout the industry.

During this reporting period we published:
15 Articles in Academic and Scientific Journals
Co-Edited a leading reference book in our field Handbook of Aseptic Processing and Packaging, 3rd Edition
12 Book Chapters
16 Conference Proceedings, Abstracts, Oral Presentations, Poster Presentations, Workshops and Symposia

2 US Patents Granted

4 International Patents Granted

Approval of funding for a collaborative project by CSIR South African Republic The Council for Scientific and Industrial Research (CSIR) is a leading scientific and technology research organisation that researches, develops, localises and diffuses technologies to accelerate socioeconomic prosperity in South Africa.

Approval of funding of a research project by CAPPS, Center for Advanced Processing and Packaging Studies, one of the US NSF funded Industry-University Collaborative Research Centers.

Approval of funding of a research project by NC State University College of Agriculture and Life Sciences.

Initiation and discussions of collaborations and joint project proposals with Josip Juraj Strossmayer University in Osijek, Croatia, Busitema University in Uganda, University of Sao Paolo in Sao Paolo, Brazil, University of Athens in Greece, Mersin University in Athens.

During this reporting period year two major food and beverage processing facilities have had ground-breaking events and started construction – after the original FirstWave Innovations facility in Raleigh NC - another one in North Carolina - FirstWave Innovations in Nash County (a division of SinnovaTek in Raleigh, NC, USA) and another one near Nairobi, the capital of Kenya. The facility in Kenya is the first facility of its kind on the African continent, both by the implemented advanced thermal technology (continuous flow microwave sterilization and aseptic packaging) and the types of products and ingredients produced (shelf stable fruit - mango and vegetable - sweetpotato purees) to be used in baby and infant foods, as well to

replace up ro 40% of the imported wheat in local bakery items and achieve a multiple purpose: increase the income base and sustainability of the local small holder farmers, reduce dependence on imported wheat at the time of global grain market disruption caused by the Russian agression in Ukraine, and adressing the primary cause of childhood blindness in sub-Saharan Africa - nutrient defficiency in Vitamin A (sweetpotato is particularly rich in beta-Carotene, provitamin A).

In addition to the intellectual property publications / patents, our teams of co-inventors and co-authors have published numerous academic studies and publications in respected national and international scientific journals, authored numerous book chapters in scientific and professional journals, gave interviews and received the highest professional awards and honors from scientific, professional and business institutes and associations as well as government agencies.

The two previously mentioned production facilities (in North Carolina and Kenya) will be soon joined by two more large industrial plants– another one in the U.S. and one in the South African Republic, as well as several small and efficient processing systems in several countries in South America.

These will be added to several previously established dedicated processing plants in the U.S. and commercial and university based R&D installations, enabling new and continued collaborations with companies and Universities in the U.S., Brazil, Croatia, Turkey, Greece, Kenya, South Africa, Uganda, Honduras and Taiwan.

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

Our research, development and commercialization activities have made possible the construction and commercial success of several new processing facilities and have brought attention to the need and ability to prevent and address food waste by implementation of advanced processing technologies. In addition to providing a commercial outlet for fruits and vegetables produced by both large and small holder farmers, processing facilities built using our patented, licensed and commercial technologies have generated introduced several hundred new products to the commercial and consumer market place in the United States and abroad. Additionally, several hundred new commercial products have been developed and introduced to the market place using the ingredient lines preserved using our technologies as high quality, nutritionally rich ingredients. The most recent efforts involve the use of microwave processed and preserved sweet potato puree to replace the imported wheat in bakery products produced and sold in several countries of Sub-Saharan and West Africa, thereby reducing the dependence on import while improving the nutritional profiles of these products. In this specific case, the inclusion of microwave processed sweet potato purees results in a bio-fortified product lines, particularly rich in beta-carotene (pro-vitamin A), which is critical in addressing infant malnutrition and childhood blindness prevention typical of poor populations in sub-Saharan Africa.

The success of our scientific and industrial processing efforts and the resulting technologies has stimulated interest in implementing these technologies to new products and processing techniques – leading to, in addition to the new advanced, microwave based thermal processing and preservation installations, to microwave-assisted extraction, evaporation, frying and drying applications in the foods and biomaterials processing industries.

Research and development and processing facilities using our technologies cover a broad range of capacities and capabilities, ranging from 1-2 liters (about 1/2 gallon) per minute all the way up to more than 20 gallons per minute of processing capacity. These facilities have enabled processing and commercialization of several hundred unique new, high quality and high nutrient retention materials, which would not have been possible without the implementation of technologies and tools developed by our teams at NC State University.

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

The impact of our microwave processing technologies has been notable in several categories:

1. Reduction of food waste and losses in post-harvest, pre-processing and post processing material categories. The best example of this has been the ability to process almost 40% of the sweet potato crop which previously has been left unused in the field due to what has been perceived as size and shape inappropriate for use in the retail markets (targeted to individual pieces for baking). Introduction of our technology has enabled the profitable use of all of the crop for production of shelf stable purees used as ingredient in development of several hundred new nutritious and flavorful products. This has benefited the growers, the processing industry and the consumers. The similar effects have been seen with the use of surplus mangoes in Africa and grape pomaces in the United States. Upcycling these materials using our technologies has provided economic, nutritional and health benefits to populations across the food production and processing industries.

2. Reduction of greenhouse gas emissions for industrial food and beverage processing and distribution. This has been achieved via two pathways:

3. The continuous flow microwave food and beverage processing technologies are electric technologies and therefore generate little to no greenhouse gases when implemented in industrial processing and preservation of foods and biomaterials.

4. The ability of our technologies to deliver top quality, high nutrition foods in shelf stable formats at ambient temperatures (12 to 18 months shelf life under typical storage conditions) has enabled the elimination of the need for refrigerated or frozen storage and distribution for these products. This has resulted in further minimization of greenhouse gas emissions but also significant energy savings, and therefore more affordable product, with simpler, better controlled processing lines and expanding packaging format options while maintaining safety, sensory quality and nutritional superiority of produced product lines

1. Introduction of new, innovative product lines, both at the retail level and the bulk ingredient levels to the domestic and international marketplace.

2. Minimization of expenses and costs of precision scale production of market-ready innovative products for smaller, more imaginative innovators in the industry by enabling production of smaller batches of unique novel, high quality products. These products in turn serve as the tools to raise investments and proceed to higher capacities and incremental scale-up to global relevance.

3. Maximization of flavor and nutrient retention in shelf stable formats of aseptic packaging ranging from individual serving sizes to large 1 ton packages to be used as ingredients for further processing and development of novel product lines using these unique ingredients

Therefore, some of the global problems our technologies are addressing are food waste, hunger and malnutrition as well as economic development in underserved areas and minimization of greenhouse gas emissions resulting from large scale industrial food and biomaterials processing.

One notable benefit has been the contribution our technology and our activities in Kenya, Africa have made on adressing the critical issue of childhood blindness in sub-Saharan Africa caused by malnutrition and vitamina A defficiencies - by preserving beta carotene in shelf stable sweetpotato purees used in local bakery products, while at the same time reducing the dependence on imported wheat at a critical time during Covid 19 pandemic. The substitution rate of 40**%** od imported wheat flowers has been enabled by using sweetpotato puree ingrediencts preserved by our technology.

These achievements have been recognized by the Tibbets award from the US Small Business Administration. The following quote is from the award announcement:

Raleigh-based SinnovaTek is having a significant impact on the lives of young children a world away in Sub-Saharan Africa - where almost half of children under five suffer vitamin A deficiency – thanks to their Nomatic processing system, and locally-available sweet potatoes.

SinnovaTek may be located in Raleigh, but the company is making a significant impact on the lives of young children in sub-Saharan Africa - where 48 percent of children under five years old suffer from vitamin A deficiency. The company?s Nomatic processing system is helping to address this issue in Kenya with the production of sweet potato puree. The Nomatic allows for high quality small scale, distributed processing for high acid and low acid shelf-stable foods when paired with the appropriate filler. Thus far, similar processing systems have only been available at large scales, with high minimum order quantities. This system now has four installations and a new manufacturing facility and subsidiary, FirstWave, that is being built around the concept of small-scale aseptic food manufacturing, and servicing customers who would not otherwise have access to high quality food processing. This unique processing system is enabling a range of projects with direct societal benefits, including improving public health due to the creation of healthy, nutrient-rich food products. Small Business Innovation Research (SBIR) funding was integral in validating the base technologies behind the Nomatic processing system. Without this key

comparison data, the system would not be as robust, nutrient analysis would not be as detailed, operating costs and yield would not be well understood, and sensory profiles would not be data-driven. In addition to moving the Nomatic processor from a testing phase to commercialization, SBIR funding has contributed to the steady employment of a team of 7 people, and the creation of a new subsidiary expected to employ 20 people by the end of 2021. SinnovaTek has seen approximately $1.5 million in sales, with 5 systems sold in 2019, another 6 projected to be sold in 2020; and, $1.3 million in further funding and investments. Through SinnovaTek's subsidiary, FirstWave, the company plans to produce for other brands at this scale. The Nomatic contributes to reduced food waste due to the small processor size, while improving access to high quality processing technology. The Nomatic system can also be used for personalized nutrition products, as it allows for processing batches as small as 5 liters, enabling customized products through an automated order system. This technology has enabled a program to sterilize orange-fleshed sweet potato (OFSP) to use in making bread to provide a rich source of natural Vitamin A to the general population. The small-scale design combined with nutrient retention capabilities of microwave processing has made this initiative possible. Nomatic is also used in research and development at university facilities, enabling the scientific and research advancement of food products As SinnovaTek continues its mission to promote worldwide health and wellness through the development of sustainable processing technologies that foster the delivery of high quality, healthy foods, it is also enabling entrepreneurs as well as large brands to produce and offer innovative products that historically have not made it to market, due to the previous inability of aseptic food production to be economically scaled.

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.

There were numerous challenges encountered due to the Covid-19 pandemic and the resulting limited and/or access to laboratory and pilot plant facilities.

These were compensated with a range of industrial activities locally and internationally and remote collaboration activities (articles, chapters and conference contribution publications).

Several project funding proposals and on-going collaborations have been submitted, resubmitted and/ or renewed nationally and internationally.

These include proposals for training for equipment and system operators, process developers, product developers and food safety program developers for a range of technologies and product lines.

The most significant development has been the USDA award to SinnovaTek initiate a commercialization program to assist the innovative local startups with introducing their new and novel products using materials sourced from the local farmers, growers and suppliers to the broader national marketplace.

Details of the program have been announced recently:

This exciting new initiative has been made possible through funding from the US Department of Agriculture's Local Food Promotion Program. "The Local Food Promotion Program (LFPP) funds projects that develop, coordinate and expand local and regional food business enterprises that engage as intermediaries in indirect producer to consumer marketing to help increase access to and availability of locally and regionally produced agricultural products."
The FirstWave Food Incubator will usher cohorts of competitive entrepreneurial brands through the commercialization process to help bring their products to market. With a planned Research & Development run and a Commercialization run, our Incubator is set up to teach our participants everything they need to know and arm them with all the resources they need to succeed.

The FirstWave Food Incubator (FFI) is a first of its kind program aimed at aiding start-ups in launching new aseptically processed foods with locally sourced ingredients.

FFI is a fully funded 8-month incubation program that will provide clear insight into the commercialization process for an aseptic product. We will train entrepreneurs in the basics of thermal processing and in the key aspects of developing and commercializing aseptic, shelf-stable consumer packaged goods. Participating companies will collaborate with our team of experts at no cost to the company to formulate products, complete feasibility trials, source ingredients, select packaging, meet labeling compliance, and achieve market readiness. Example products include fruit and vegetable purees, soups, sauces, smoothies, juices, beverages, plant-based milks, and baby foods. At the end of the program, participants will have a fully commercializable product formulation as well as finished products ready to sample to investors, retailers and potential

consumers. The first of 4 cohorts begins in June 2023 with applications now open.

The FirstWave Food Incubator may be a good fit if:

- You are a small business looking to launch a product in the aseptic food space.
- You have a concept, recipe, or full formulation for a liquid or puréed food product.
- You intend to source local ingredients within 400 miles of Raleigh, NC.
- Your concept can be packaged in 3.2 oz, 4 oz or 8 oz spouted pouches.
- Your product vision includes sustainability and/or waste reduction.

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.

IMPROVED FOOD QUALITY AND SAFETY THROUGH NEW ENERGY-EFFICIENT, MICROWAVE-BASED PROCESSING METHOD: Conventional food processing degrades flavor, color, quality, and nutritional value. To address this problem, NC State researchers worked with international partners to develop a new, energy-efficient microwave heating technology, followed by packaging into flexible, sterile packaging of diverse sizes. In 2022, two processing facilities employing this technology were constructed and put into operation, one in NC and another in Kenya. Both facilities enhance food safety and quality and reduce greenhouse gas emissions. The Kenyan facility is the first of its kind in Africa, and it is producing shelf-stable products that not only enhance the local economy but also reduce severe childhood nutritional deficiencies and the region's dependence on imported grain during a time of heavy market disruption. In addition to maximizing the preservation of sensitive flavors and nutrients and extending shelf life without refrigeration to 12–18 months at ambient temperatures, this technology minimizes or eliminates food waste and reduces processing time and costs. In the first year of its operation, the NC processing facility has been instrumental in the commercialization of over 70 new food products. This new technology has also led to the publication of 15 articles, 12 book chapters, 16 presentations, 2 US patents, 4 international patents, and a collaboration with South African partners to expand the commercialization of processed sweet potato products in the region. In addition, a larger capacity processing facility is being opened in NC, and more facilities are pending in Africa, South America, and the US.

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

x

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.

x

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

x

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

x

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.

x

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

Final Result

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 alternatives 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.

Objective 1-3: We evaluate insect repellency and insecticidal potentials of some GRAS essential oils (EOs) (including cinnamon, clove, thyme, oregano, and orange terpene oils) at concentration 1-20% against the maize weevil using an olfactometer and a simulated fu-migation method, respectively. The olfactory tests show that cinnamon oil had the highest and reproducible re-pellency (90%) to the weevils among the EOs tested. Within the EO concentrations tested and the repellency potential of EO was not concentration-dependent. The insecticidal activity study indicates that maize weevil mortality increased with EO concentration and storage time with cinnamon, clove, and thyme oils being more effective. No weevil death was observed at 1% EOs, weevil mortality was 3.3-36% at 5% 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-positive control at its recommended concentration (5mg/kg corn). No significant increase in weevil mor-tality was observed with further increase of EO concentration with exceptions of oregano oil and thyme oil. The highest weevil mortality were observed at week 7 for 15% cinnamon oil (100%) and eugenol (100%), followed by 20% thyme oil (93%). There was no synergy between clove oil and cinnamon oil although they have significantly different chemical compositions.

Objective 3-4: We tested the antifungal activities of six EOs against the molds isolated from naturally molded organic corn grains. The effects of six EOs on the growth of total mold, *Aspergillus spp.*, *Penicillium spp.* and *Fusarium spp.* were tested using potato dextrose agar (PDA), Czapek yeast extract agar (CYA), malt extract agar (MEA) and Malachite Green Agar (MGA 2.5) plates containing different concentrations of EOs (0-0.8 mg/ml), respectively. The growth radial was measured after 7-day incubation at ambient temperature (22 ?C), and the antifungal index (AI) of each treatment was calculated. The experiment was repeated six times at each concentration. The results show that different mold species were present in the stored organic grains. The growth of total mold, *Aspergillus spp.* and *Penicillium spp.* were completely inhibited at 0.2mg/mL of eugenol, 0.4mg/mL of cinnamon oil and oregano oil, 0.6mg/mL of thyme oil and 0.8 mg/mL of clove oil. The *Fusarium spp.* was more

sensitive to EOs and were completely inhibited by 0.01 mg/mL of cinnamon oil and eugenol, 0.05% of clove oil and oregano oil. Overall, cinnamon oil and eugenol were more effective against all mold species tested in this study, and the *Fusarium spp.* which produces mycotoxins such as fumonisins and vomit toxins can be completed inhibited at very low concentration.

Objective 5: We also investigated the antifungal potentials of clove oil, cinnamon oil, regano oil and thyme oil for organic corn grain protection by a simulated fumigation method at EO concentration 10% using commercial fungicide Pyraclostrobin as positive-control and 10% DMSO as negative-control. Corn grains with and with out EOs were stored at 25-35 ?C and water activities (aw) 0.85 and 0.9 for 5 weeks. The samples were examined weekly for mold growth and aflatoxins in the samples were determined by ultra-high-performance-liquid-chromatography (UPLC). The study found that the mold growth and aflatoxin contents of corn grains were affected by the type of EO, storage temperature and moisture or water activity. At 25°C and aw=0.85, negative-control was molded at week 4, while others were not molded; aflatoxin B1 and B2 were almost unchanged in positive-control and cinnamon oil treated samples; aflatoxin G1 and G2 were below the detection limit in positive-control and EO-treated samples. At 35°C, the negative-control were molded in one week at aw=0.9 and 2 weeks at aw=0.85, while samples treated with fungicide and cinnamon oil were not molded until week 4 and 5, respectively. Lowest aflatoxin B1 concentration was detected in the samples treated with cinnamon oil, oregano oil and positive control. The results indicated that cinnamon oil and oregano oil at concentration 0.5ml/100g corn grains have great potential to replace toxic fumigants to protect organic grains from mold and mycotoxin contamination during storage.

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

The target audience of benefited from this project include (1) grain farmers and processors who needs to store their cereal grains at warm and humid season for 1-2 months; (2) consumers who store grains such as beans and peanuts at home after the package being opened; (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.

Due to the effects of Covid-19, infection of students, equipment breakdown, 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.

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 trained to conduct experiments on the fungicidal activity of 4 essential oils, record the moldy status of corn grains, extract, purify and analyze aflatoxins for the Master's thesis. Due to the breakdown of HPLC and there was no expert to operate the UPLC in college's analytical time, the aflatoxin concentrations of her samples could not be quantified. Thus, she switched to non-thesis option and graduated in December 2021.

- Graduate student Esther Iwayemi: She was trained to conduct microbiology aspect of the project, she completed the effects of single essential on on the growth different species of grain storage molds and 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, different conference presentations, and publications. So far, we have submitted 3 manuscripts (one is published), 4 oral presentations and 6 poster presentations.

Publications:

1. Eesiah, S.; Yu, J., Dingha, B., Amoah, B., Mikiashvili, N. (2022). Preliminary Assessment of Repellency and Toxicity of Essential Oils against Sitophilus zeamais Motschulsky (Coleoptera: Curculionidae) on Stored Organic Corn Grains. *Foods*, *11*(18), 2907; https://doi.org/10.3390/foods11182907

2. Yu, J., & Pedroso, I. Mycotoxins in Cereal–Based Products and Their Impacts on the Health of Humans, Livestock Animals and Pets. Submitted to *Toxins* on December 15, 2022,

3. Yu, J., Iwayemi, E., Pedroso, I., & Mikiashvili, N. Fungicidal Potential of Essential Oils in Organic Corn Grains during Storage. Submitted to the "Proceeding of National Conference on Next Generation Sustainable Technologies for Small Scale Producers". Godfrey A. Uzochukwu (Editor).

Oral presentations:

- Yu, J., Eesiah, S., Mikiashvili, N., Amoah, B., Dingha, B. Insect Repellency and Insecticidal Potentials of Some GRAS Essential Oils Against Maize Weevil in Stored Organic Corn Grains. 2022 ARD Research Symposium, April 2-5, 2022, Atlanta, GA.

- Jianmei Yu. Controlling Insects and Mycotoxins in Stored Cereal Grains by Essential Oils. Seminar in FCS 789 class, April and November, 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. (Received Brown Award)

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

Poster presentations

- Iwayemi, E., Yu, J., Davis, S., & Williams, L. L. Antifungal Activities of Essential Oils against Different Species of Grain Storage Molds. Submitted to 2023 IFT FIRST.

- Iwayemi, E., Yu, J., Davis, S., & Williams, L. L. Inhibitory Activities of Some Essential Oils Against Molds Extracted from Organic Corn Grains. Submitted to 2023 ASM Microbes.

- Iwayemi, E., Yu, J., Pedroso, I., & Mikiashvili, N. Fungicidal Potential of Essential Oils in Organic Corn Grains during Storage. Poster presentation in National Conference on Next Generation Sustainable Technologies for Small Scale Producers. September 7-9, 2022, Greensboro, NC.

- Yu, J., & Mikiashvili, N. Inhibitory Effects of Essential Oils on Mold Growth and Aflatoxins Formation in Organic Corn Grains during Storage. IFT FIRST 2022, July 10-13, 2022, Chicago, IL

- Mikiashvili, N., Pedroso, I., & Yu, J. Inhibition of Essential Oils on Mold Growth and Aflatoxins Formation in Organic Corn Grains during Storage. 2022 NCAFCS Annual Conference, March 3-5, 2022. Kitty Hawk, NC

- Pedroso, I. R., Mikiashvili, N., & Yu, J. Quantification of aflatoxins in organic corn grains by a pre-column derivatization HPLC-FLD method. Poster presentation, 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. Poster presentation, 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. Poster presentation, IFT21 Virtual Meeting, July 18-21, 2021

Project Plan: Based on the research finding obtained so far, I plan to submit one more manuscripts for publication and one grant proposal for funding to expand the research in the grain protection using essential oils. The possible funding agencies are USDA-NIFA's AFRI program and CBG program or NC Department of Agriculture and Consumer Services.

Flavor and flavor chemistry of dairy products.

Project Director
MaryAnne Drake
Organization
North Carolina State University
Accession Number
1016957

Annual Result: Flavor and flavor chemistry of dairy products

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

Nutritious foods that are appealing to consumers is a benefit to all members of society. This project seeks to identify processing methodologies and consumer insights to optimize flavor of high protein foods, both plant and dairy-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.

Studies were conducted focused on consumer insights and sensory quality of dairy products (yogurt and protein beverages) and plant products. These results were disseminated by presentations at key stakeholders, national and international meetings and peer-reviewed publications. Yogurt sales in the US continue to increase. Consumers are interested in products with reduced sugar, a trend which has been attributed to consumers associating high-sugar foods with obesity, diabetes, heart disease and high blood pressure. It is important to understand how consumers perceive label claims regarding sugar and other sweeteners and how sweetener type impacts liking of yogurt. The objective of this study was to evaluate consumer perception of sugar reduction in yogurt – both conceptually and for liking of actual products. An online survey (n=1290) was conducted to evaluate consumer perception of sweeteners available in commercial yogurts. Participants who purchased

yogurt at least once in the past 3 months were shown Maximum Difference (MaxDiff) questions regarding sugar claims and sweeteners in yogurt. Subsequently, vanilla 1% milkfatyogurts sweetened with sucrose were formulated to iso-sweet taste intensity with either stevia, allulose, a blend of sucrose and honey or a blend of sucrose, stevia and allulose using magnitude estimate scaling followed by paired comparison tests with consumers (n=40). A consumer acceptance test (n=229) was then conducted using the five vanilla yogurts. Half of the consumers (n=115) were primed with the specific yogurt sweetener and the other half were not. Conceptually, consumers preferred the claim "naturally sweetened" over a reduced sugar claim in yogurt. Honey was preferred over other sweeteners, followed by agave nectar and cane sugar. Allulose was the least preferred sweetener option conceptually. When yogurts were tasted, yogurt sweetened with sucrose was preferred and yogurt sweetened with stevia was the least preferred, regardless of priming ($p<0.05$). Priming with sweetener type positively impacted yogurt sweetened with a sucrose/honey blend ($p<0.05$) but had no impact on the other four sweetener/sweetener blends ($p>0.05$). Consumers are interested in healthy yogurts that are naturally sweetened, and flavor remains the driving force for liking and purchase. The use of a natural non-nutritive sweetener that delivers the sensory experience of sucrose is ultimately more important than familiarity with the actual sweetener.

Foods that meet immune boosting and calming need states are in high demand from pandemic-related consumer shifts in purchase motivations. Dairy products offer a wide range of intrinsic and extrinsic properties which may deliver these need states. The objective of this research was to identify extrinsic (package, labeling, messaging) and intrinsic (composition, flavor, texture) properties of dairy foods that are perceived as calming/immune boosting. Dairy consumers (n=622) completed an online survey to document motivations and goals for consuming dairy products. Consumers were presented with psychographic, agree/disagree, and maximum difference (MaxDiff) scaling exercises. Cognitive memory recall questions connected emotional need states with dairy usage. Univariate and multivariate statistics were used to evaluate survey data. Subsequently, eight 2-hour immersive qualitative focus groups were conducted with selected consumers (n=48). Qualitative insights from a moderator-guided discussion were used to create an attribute drivers database, benefits hierarchy, and consumer co-creation ideation. Some consumers currently associate dairy products with calming and immune boosting. A quarter surveyed don't use dairy for these needs but would like to. Cultured dairy products are associated with immune health (48%) and ice cream is associated with calming (69%), while milk and cheese can cross both need states. Creaminess is the key desirable sensory attribute missing in non-dairy immune boosting and calming products. Each need state has two 'need moment' dimensions with different intrinsic and extrinsic attribute drivers: 1a) Immune boosting for prevention, 1b) Immune boosting for lifestyle health; 2a) Calming for stressful event, 2b) Calming for baseline stress reduction. Messaging that identifies nutritional elements inherent in dairy products that impact immune and mental health, along with scientific support, resonated most for consumers who are not currently using dairy for need states. Credibility is the primary barrier for immune boosting products, while added sugar and carbohydrate content are the primary barrier for calming products. Consumers are reaching for current dairy products for immune boosting (probiotic yogurts) and calming (ice cream) benefits, but there is opportunity within the greater dairy category landscape to better satisfy these need states with new products.

The plant-based food market has experienced a steady increase over the past decade. Plant-based dairy alternatives (PBDAs) are part of this increasing market and there is a need to understand the sensory properties of these products and to document how they are distinct from their traditional dairy counterparts (TDC). The objective of this study was to identify a sensory language to provide a standardized tool to identify and quantify the flavor and texture attributes of PBDAs. Subsequently, projective mapping (PM) was applied to further characterize differences among PBDAs and traditional dairy foods. Fifty-seven commercial PBDAs (yogurt (n=21), cream cheese (n=7), and cheese (shredded and sliced) (n=29) were collected in duplicate lots. A highly experienced panel (n=7) identified attributes and definitions for the lexicon. Products were then evaluated monadically in triplicate by each panelist. Six to eight products were evaluated per session overthe course of twenty-eight sessions. Subsequently, PM was conducted on representative PBDAs and TDC to further characterize sensory differences among products. Twenty-six aromatics, five basics tastes, astringency and burn were documented in the plant-based flavor lexicon. An additional 16 attributes were applied to document texture. Eight flavor attributes were unique to PBDAs and not previously documented in TDC. Key differentiating attributes among PBDAs were the aromatics, diacetyl, sour aromatic, coconut and beany, sour, umami, and sweet tastes, and the texture attributes oral smoothness and cohesiveness. Descriptive analysis with the identified lexicon and PM demonstrated that PBDAs were diverse in sensory properties and remained distinct from TDC. Higher intensities of sour aromatic and cardboard flavors and sour taste in conjunction with umami taste, plant protein-specific aromatics and lack of milky flavor were the sensory properties that distinguished the flavor of PBDAs from TDC. Lack of oral smoothness and cohesiveness and a faster oral melt were the key texture attributes that distinguished PBDAs from TDC. The determination of the sensory properties specific to PBDAs can be used by product developers for development and characterization of PBDAs with desirable sensory properties.

The protein beverage category continues to grow and consumers are seeking variety. As such, understanding the role of milk components on milk beverage physical and sensory properties is crucial. Our objective was to progressively remove lactose and other low molecular weight soluble compounds from milk (ca. 0, 30, 70 and 98% removal) using ultrafiltration (UF) in combination with diafiltration to determine the impact of four fat levels (skim, 1%, 2% and 3.5% fat) and three protein levels (3.3%, 6.5% and 10.5% true protein) on chemical, physical, and flavor of milk-based beverages. These experiments were

replicated twice followed by instrumental analysis (proximate analysis, pH, titratable acidity, color, viscosity) and trained panel profiling. Instrumental color (L-values, whiteness) increased with lactose removal, but the effect of increasing fat and protein concentration on L-value was larger than lactose removal. Yellowness scores and b*-values decreased with increasing lactose removal. Apparent viscosity decreased with increasing lactose removal but the magnitude of decrease was small. Titratable acidity (TA) decreased from about 0.17% to 0.04% with increased lactose removal at all fat levels. TA increased with increasing protein concentration. TA at all protein levels decreased with increasing lactose removal. At the different fat and protein levels, the pH of the UF retentate at 20oC increased from about 6.6 to 7.3. Lactose removal increased sensory whiteness and decreased yellowness, concurrent with instrumental analysis. Lactose removal decreased sweet aromatic flavor and sweet and salty tastes while opacity and viscosity increased with increasing protein and fat concentration. Increased protein also increased astringency. With removal of lactose and other low molecular weight compounds, the liquid UF beverages were more white in appearance and more bland in flavor, making UF milk an ideal base to adjust sweetness and add novel flavors while providing lactose free beverages over a range of fat and protein concentrations

As the protein beverage category continues to increase, consumers desire ingredient decks were fewer ingredients. Dipotassium phosphate (DKP) is a stabilizer that may not be required, but is frequently used in ingredient decks. An additional study was undertaken to determine the impact of dipotassium phosphate (DKP) on protein beverage stability.

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

An understanding of the role of unit processing operations on flavor and ways to control flavor and an increased understanding of consumer perceptions and desires as they relate to dairy and plant proteins and sustainability provide actionable information to food processors to provide nutritious and appealing foods.

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

Nutritious foods that are appealing to consumers is a benefit to all members of society.

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.

DELIVERED CONSUMER INSIGHTS FOR IMPROVED DAIRY PRODUCTS AND PLANT-BASED DIARY ALTERNATIVES: Consumer demand is increasing for plant-based dairy alternatives (PBDAs) and dairy products with reduced sugar. Pandemic-related consumer motivation shifts have also led to increased demand for food products that offer immune-boosting and calming effects. To meet these demands, NC State researchers conducted studies on consumer insights and the sensory quality of PBDAs, disseminating results to key stakeholders at national and international meetings and in peer-reviewed publications. These studies reveal that consumers prefer yogurt products labeled as “naturally sweetened” over those that emphasize reduced sugar. Honey was preferred over other sweeteners, followed by agave nectar and cane sugar. Yogurt sweetened with sugar was preferred, and yogurt sweetened with Stevia was the least preferred. These studies reveal that taste remains the driving force for consumer preference, and the use of a natural low-calorie sweetener that delivers the sensory experience of sugar is more important than familiarity with the sweetener. An online consumer survey and focus groups revealed that 48% of consumers associate cultured dairy products with immune health, 69% associate ice cream with calming properties, and creaminess is the key attribute missing in non-dairy immune boosting and calming products. This research reveals important opportunities for industry to better satisfy consumers’ needs. Researchers also created and validated a standardized tool for characterizing differences between PBDAs and dairy products, including PBDA’s lack of textural smoothness and the presence of unique plant-based flavor profiles. Product developers can use these insights to develop and evaluate PBDAs with desirable tastes and textures.

delete

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

x

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.

x

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

x

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

x

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.

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Sensory and Chemical Characterization of Green and Roasted Coffee as a Means of Improving Coffee Shelf Life and Understanding Potential Health Effects

Project Director
Gabriel Harris
Organization
North Carolina State University
Accession Number
1017092

Sensory and Chemical Characterization of Green and Roasted Coffee as a Means of Improving Coffee Shelf Life and Understanding Potential Health Effects

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

First, our project addresses **green and roasted coffee quality**. While most of the focus (and profits) are related to coffee and coffee processing post-roast, green coffee quality is vital to the ultimate quality of any coffee product. In the context of coffee products, we have invented a new process for the infusion of fruit flavors and nutrients into coffee beverages. We have also started undergraduate research projects examining sustainable coffee processing.

Second, there is evidence that **coffee may benefit health** in a number of ways. We have examined the role of coffee in regulating blood sugar and on anaerobic exercise performance. We have also started undergraduate research projects examine dental health and anti-cancer properties of coffee.

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.

Regarding **green and roasted coffee quality**, we were able to show in a published study that microwave processing of coffee was effective at extracting coffee and produced a beverage with similar chemical and sensory properties to cold brew. We also created, and are now pursuing a patent for the infusion of fruit flavors and nutrients into coffee. Regarding sustainability, we have have been investigating low water used methods of coffee production to compare physical and chemical characteristics of more sustainable methods to conventional methods.

Regarding **health effects**, we have completed a clinical trial and are now preparing a manuscript on the effects of coffee on blood glucose regulation. This is important because there is some evidence that coffee consumption may be preventive for type II diabetes. We have also run a pilot clinical trial in collaboration with Elon University examing the effects of coffee and coffee roast on anaerobic performance. A final health-related topic, using quinine this time as a stand in for other bitter beverages examined the effects of bitter beverages on mobility for the elderly.

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

Our **green and roasted coffee quality research** served coffee consumers that may purchase coffee as a ready-to-drink beverage and for those consumers who may wish to benefit from the flavors and nutrients fruit provides while consuming an energizing coffee beverage. Investigating low water use processes benefits the environment of coffee growing regions and ensures a sustainable supply of coffee in CONUS.

Our **health effect-related research**, described previously, benefited populations predisposed to disregulated glucose (coffee and glucose regulation trial) active populations (anaerobic study), and elderly populations (quinine/bitter beverage clinical trial).

We have published two peer-reviewed papers, submitted one invention disclosure, presented one poster, and submitted an abstract for a poster presentation (accepted for presentation in 2023).

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

While some of our quality research may benefit both industry and the broader public, we believe that most of the work described previously benefits the broader public, including coffee producers outside CONUS, because it relates to public health and to the productivity of the green coffee commodity.

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.

Problems with our research projects have included the following:

- Broken equipment, which hindered our ability to complete the anaerobic exercise clinical trial.
- Helium is in short supply, so that our ability to conduct GC-MS research may be hindered.

As a result of the above challenges, we have responded in the following ways:

- We have expanded the number of pieces of equipment used to measure anaerobic performance, so that the failure of one will not greatly hinder data collection and publication.
- We are switching our GC-MS protocols over to nitrogen, since nitrogen is not in short supply (we're breathing it).

Opportunities for training:

- Our collaboration with Elon University have opened opportunities for training on anaerobic exercise measurements.
- We have actively collaborated with industry partners and brought members of the lab along to improve their understanding of industry processing methods.
- Our undergraduate researchers have gained hands-on experience in chemical, microbial, and cell culture-based areas of expertise.

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.

ENHANCED COFFEE PRODUCT QUALITY AND KNOWLEDGE OF COFFEE'S HEALTH BENEFITS: Coffee is the third most widely consumed beverage worldwide, and consumers are becoming increasingly aware of the quality, sustainability, and health issues surrounding the coffee they drink. Coffee consumption has also been associated with a decreased risk of chronic

disease, including type II diabetes. To enhance the quality of coffee products, NC State researchers have invented and are pursuing a patent for a new process for infusing fruit flavors and nutrients into coffee beverages. They have also demonstrated the effectiveness of a new microwave coffee extraction method and begun investigating sustainable, low-water-use methods of coffee production. In addition, researchers have completed a clinical trial and are preparing a manuscript on the effects of coffee on blood sugar regulation, and they completed a joint clinical trial with Elon University examining the effects of coffee and coffee roasting methods on athletic performance. This research has led to 2 peer-reviewed papers and an invention disclosure, delivering insights and methods that will benefit not only industry but also consumers in general.

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

x

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.

x

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

x

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

x

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.

x

Implementation of CRISPR-based technologies in food bacteria

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

Final Result: Implementation of CRISPR-based technologies in food bacteria Final Result

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. dairy products like cheese and yoghurt, and many fermented vegetables) and also as dietary supplments (e.g products). In this project, we develop and deploy CRISPR-based technologies in food bacteria to alter the genomes and by extesnion the functional attributes of bactria usd in food products. In the past year, we have continued to harnessed various endogenous and portable CRISpr-Cas systems in probitic bactreria 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 (e.g. *Lactobacillis* strains used as dairy starter cultures) and as probiotics (e.g. *Lactobacillis* and *Bifidobacterium* strains used in dietary supplements). 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, importantly, we have engaged in several collaborations with industry leaders (DuPont-IFF, Syngenta) and biotechnology start ups (TreeCo, Ancilia Biosciences, Provaxus), to access our technologies and bring CRISPR solutions to the market.

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

There are various stakeholders beneficially impacted by our activities, including students, industry partners and consumers. With regards to students, we are mentoring and developing a dozen gradute and undergradute students in microbiology, food science and genetics, and our lab graduates continue to get hired in the food, biotech and ag industry (our 2022 PhD graduate now works at a genome editing startup in RTP). Our industry collaborators continue to engage with us, fund our work and license out technologies. Recently, our work with DePont-IFF has yielded advances in probiotic engineering and commercial formulation; our work with Syngenta is brining CRISPR-based technologies for plant and crop breeding; our work with Ancilia is enabling fundraising for a new biotech start up; our work with Provaxus is enabling the pending launch of a new probiotic commercial product, internationally. Critically, consumers 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 an Ag industry to enhance the food supply chain, especially fermented dairy products (yoghurt and cheese), to promote human health and nutrition. Also, technology developed in the lab and licensed to a local start up has enabled the formulation of novel therapeutics recently successfully and safety tested in the clinic, to combat infectious disease and antibiotic resistant bacteria. Importantly, some of our genome editing technologies that have been patented and licensed are also being deployed outside of food fermentations in crops, livestock and even trees to breed a more sustainable and resilient food supply chain, providing tangible benefits to consumers and sustainability benefits to the planet.

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 18 manuscripts in the scientific literature, given over 60 talks and technical presentations at seminars and scientific conferences, collaborated with start-up companies (TreeCo, Ancilia Biosciences, Provaxus, CRISPR Biotechnologies) and industrial partners (Syngenta, IFF-DuPont, Intellia Therapeutics). Several speaking engagements on committees (including with the National Academics of Sciences and Engineering) are advancing public engagement, science communication and regulatory poligies (including with FDA, EPA and USDA). Trainees have developed in the classroom and in the lab, with one additional PhD graduate (16 total MS and PhD students have graduated in the past 10 years and all have secured jobs in the ndustry), 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 communications media and options dictated by pandemic-related constraints. Despite challenged inherent to operational limitations related to the pandemic and limited travels, as well as contextual issues related to employee engagement and student mental health, the lab continues to be very productive, impactful and is using these challenges as opportunities to navigate difficult contexts and build resilience across the board.

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.

ADVANCED GENE EDITING OF BENEFICIAL BACTERIA TO IMPROVE FOOD SECURITY AND HUMAN HEALTH: Bacteria play important roles in various habitats, and they have been studied extensively given their roles in human health and disease. A diversity of bacteria are used throughout the food supply chain and as dietary supplements. To better understand and

enhance the safety and efficacy of beneficial bacteria and support development of a more robust food supply, NC State researchers are developing and using CRISPR-based gene editing technologies to study and modify bacterial strains. These efforts include the development of novel technologies that enable genetic manipulation of food microbes for use in fermentation and as probiotics, collaborations with industry and academia to commercialize new technologies and products, and training the next generation of scientists for fruitful careers in food, biotech, and agriculture. Researchers have published 18 manuscripts in the scientific literature and given over 60 talks and technical presentations at seminars and scientific conferences. They have also collaborated with start-up companies and industrial partners to support new product and biotech start-up launches, advance plant and crop breeding techniques, secure new patents, create novel clinical therapies, and much more, with a focus on fostering a healthier, more secure population and planet.

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

x

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.

x

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

x

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

x

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.

x

Food Safety and Nutrition

Project Director
Lauren Hargrave
Organization
North Carolina Agricultural and Technical State University
Accession Number
7001847

Annual Result: Expanded Food and Nutrition Education Program (EFNEP)

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

Obesity is associated with various physical and mental diseases, causes additional healthcare costs and productivity losses, and reduces the nation's military readiness. Examples of consequences of obesity include higher rates of complications and severe illness from COVID-19, Type 2 diabetes, high blood pressure, heart disease, stroke, arthritis, depression, sleep apnea, liver disease, kidney disease, gallbladder disease, pregnancy complications, and many types of cancer—and an overall risk of higher mortality. Children with obesity are also at greater risk for diseases like Type 2 diabetes, high blood pressure, and

depression. Nutrition insecurity is a significant national health concern, especially among low-income populations that disproportionately experience poor health. Often associated with food insecurity, nutrition insecurity is characterized by poor nutrition, limited physical activity, and unsafe food practices.

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 Expanded Food and Nutrition Education Program (EFNEP) is the nation's first nutrition education program for low-income populations. It remains at the forefront of nutrition education efforts to reduce nutrition insecurity of low-income families and youth.

EFNEP addresses the problem of food insecurity and limited nutrition knowledge among low-income families by utilizing various nutrition curriculums. EFNEP is a federal program that provides education and resources to help families with limited income make healthier food choices and stretch their food budgets. The program teaches families about good nutrition, food safety, meal planning and preparation, and physical activity. Through EFNEP, families learn how to choose and prepare nutritious foods that are affordable and accessible and how to make healthy food choices within the constraints of their budgets. EFNEP also works to increase food security and reduce poverty by providing education and resources on budgeting, meal planning and nutrition and by linking families with other community resources.

In 2022, four EFNEP educators were trained in Vance, Warren, Martin, Guilford, and Durham counties. The educators conducted programs to educate community members on the importance of nutrition.

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

The EFNEP programs reached 84 adults and 199 individuals from their families. A total of 96% of participants showed improvement in one or more diet quality indicators (i.e., eating fruits, vegetables, red and orange vegetables, dark green vegetables, drinking less regular soda, not diet, consuming less fruit punch, fruit drinks, sweet tea, or sports drinks, and cooking dinner at home). Eighty of 84 participants (95%) showed improvement in one or more food resource management practices (i.e., cooking dinner at home, comparing food prices, planning meals before shopping, looking in refrigerator or cupboard before shopping, or making a list before shopping). 40 of 84 participants (48%) showed improvement in one or more physical activity behaviors (i.e., exercising for at least 30 minutes, doing workouts to build and strengthen muscles, or making minor changes to be more active). 50 of 84 participants (60%) showed improvement in one or more food safety practices (i.e., washing hands before preparing food and washing all items and surfaces after). 33% of the 28 participants showed improvement in one or more food security indicators (i.e., not eating more than you need, so there is more food for the family or having enough money to get food for your family).

The EFNEP program also reached 800 youth in 2022 through direct programming.

Of those youth, 87% improved their abilities to choose foods according to Federal Dietary Recommendations or gained knowledge. 69% of the youth reported using safe food handling practices more often or gained knowledge about food handling. 67% improved their physical activity practices or gained knowledge. 65% improved their ability to prepare simple, nutritious, affordable food or gained knowledge. 53% of youth acquired skills to be food secure or gained knowledge.

In Vance County, the Kids in the Kitchen-International Culinary Cuisine cooking camp addressed problem areas such as providing recipes for families to prepare and eat at home. The program was designed to increase physical activity. This program was innovative in teaching new skills to help families overcome barriers to healthy eating and physical activity. Students were able to enjoy themselves with creative play instead of intense exercises. Students gained culture by finding new favorite healthy recipes from countries they had yet to visit. Participants gained experience that fueled their confidence in the kitchen when assisting their families in providing healthy dinner options. The 4-H and EFNEP agents met with students in grades 3-6 at Aycock Recreation Complex for a seven-session international culinary fest where students created International Kids in the Kitchen recipes from countries like Mexico, Australia, Kenya, Japan, Thailand, and Ethiopia. They also studied curriculum to learn nutrition fundamentals such as increasing fruit, vegetable, and water consumption. Students learned the importance of proper hand-washing techniques and engaged in healthy physical activities by building a djembe, learning salsa dance, and sculpting traditional Tanzanian art.

After completing the lessons, survey results show that youth improved in the following ways:

- 100% improvement in the frequency of eating vegetables as a snack in the past week.

- 100% improvement in the duration of physical activities.

- 60% improvement in putting cold foods back in the refrigerator right away.

- 60% improvement in frequency of physical activity in the past week.

- 60% improvement in non-homework screen time in the past week.

Each parent shared how they enjoyed 90% of the recipes created. Parents enjoyed the freedom of having the monthly educational sessions at the local community recreation complex. The partnership between Vance County Cooperative Extension and Henderson Parks & Recreational Complex provides support and growth for the future of the community. Through changing behavior, this cooking camp helped families save money on potential healthcare costs by the reducing risk factors of obesity. Vance County Cooperative Extension has connected families to additional community resources.

The FCS and 4-H agents in Stanly County partnered to offer a 4-H Cooking Club called Kids in the Kitchen. Approximately 30 youth registered to attend the interest meeting held in March 2022. The goal for this group was to gain confidence in the kitchen and in growing foods to encourage the consumption of more fresh foods and improve health outcomes. For this project, Extension received $3,000 in grant funds to create an edible garden in the teaching garden outside the Extension Office in Stanly County. The 4-H Cooking Club used this garden as the group learned to make various recipes and learn multiple cooking skills. We plan to partner with our Stanly County Master Gardeners to keep these edible plants healthy. In addition, Master Gardeners agreed to contribute funds to increase the number of raised beds in the teaching garden. The raised beds have been purchased and placed in the teaching garden as of this year. Our Extension Master Gardeners have worked hard to complete the teaching garden while adding edible plants, such as greens and herbs, to the raised beds. Our 4-H Cooking Club has already been able to use the edible plants from the raised beds to make fresh salads during their club meetings. The FCS, 4-H, and Ag programs in Stanly County look forward to utilizing the beds and teaching gardens in 2023.

Based on the Eat Smart, Move More curriculum, the Warren County EFNEP agent created the Breakfast of Champions program to provide families with healthy breakfast choices during the holiday season. Nine participants registered for the program through Eventbrite. Youth in grades 1 – 6 completed the virtual seven-week program alongside their parents. The Lake Gaston community enjoyed this phenomenal virtual educational experience. Five attendees gathered in their kitchen around laptops each Friday to learn quick, healthy, and convenient breakfast choices the family could make for Thanksgiving, Christmas, and New Year's Day. Warren County EFNEP wanted to design a plan that allowed families to sign up for the Breakfast of Champions program, where families learned the importance of food and nutrition. The participants completed EFNEP pre/post surveys and sent testimonials and pictures capturing their achievements and delight throughout the holiday season.

Here are a few testimonials from the families:

"The kids have really enjoyed discovering different healthy breakfast options. They make breakfast with little assistance most days during the week. It's great to see them scrambling eggs or flipping pancakes instead of packaged sugary options being the go-to. They look forward to our class each week, and I'm so proud of their new confidence in the kitchen. Thank you!"

"The French toast was a big success. They took care of the whole process from start to finish and even made some scrambled eggs to go with it. Our chickens from 4-H in the spring have started laying, so they gathered the eggs, washed them, and then prepared them. It's a great experience."

"They liked that this was pretty easy to assemble. All the kids were skeptical of trying it, but they all loved it. It had great flavor, and they were already talking about making it again or trying different versions of it." The Warren County EFNEP educator hopes to have the opportunity to provide this program to other families each year during the holiday season because of the enormous impact on the participating families.

To have a healthy body, we look not only on the outside but also on the inside. The EFNEP educator in Guilford County taught 25 adults virtually, including some aging participants and five of their children and grandchildren, to make healthier choices, save money, and move more. Each lesson included a live food recipe cook-along, a physical exercise, and nutrition

information. Thanks to Mustard Seed Community Health and the funds available to the EFNEP educator, participants were provided with the ingredients to prepare the recipes at no cost. While conducting classes, participants were encouraged to engage with one another, and different genres of music were played to promote movement. Before beginning classes, many participants suffered from social depression as they could not connect with family and friends as they had before.

Along with depression came unhealthy eating habits and lack of movement. Once the participants attended all necessary sessions and could graduate, the EFNEP educator planned an in-person experience. Being able to meet each family in person was phenomenal. Participants expressed gratitude for being given the knowledge to eat healthier and save money while preparing healthy meals for their families. Through the EFNEP classes, approximately 21% of participants were able to lose weight, and a couple struggling with diabetes was able to lower their A1C by 2%. Health is not only physical, but it is also a mindset. The EFNEP educator in Guilford County is thankful for the dedication that each participant had to create a better future for themselves and their families by making healthier choices and moving more.

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

EFNEP benefits the public in several ways. First, by providing nutrition education and resources to low-income families, EFNEP can help to improve the overall health and well-being of these families. This can include reducing obesity and other diet-related chronic diseases, such as diabetes and heart disease, as well as increasing food security and improving the quality of life for families. Additionally, by teaching families how to make healthier food choices and stretch their food budgets, EFNEP can help to reduce poverty and improve economic stability for low-income families. This can also positively impact communities, as families with more financial stability can better participate in community activities and support local businesses. EFNEP also benefits the greater public by reducing healthcare costs. By helping to prevent and manage chronic diseases, EFNEP can lessen the need for medical care, ultimately saving money for individuals and the healthcare system.

Furthermore, EFNEP can also help to improve public health by providing education and resources on food safety, physical activity, and other health-related topics. This can help to prevent foodborne illnesses, reduce the risk of injuries and accidents, and promote overall health and well-being for everyone. EFNEP benefits the greater public by improving the health and well-being of low-income families, reducing poverty and healthcare costs, and promoting public health, ultimately leading to stronger communities and a better quality of life for everyone.

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 Expanded Food and Nutrition Education Program (EFNEP) is the nation's first nutrition education program for low-income populations. It remains at the forefront of nutrition education efforts to reduce nutrition insecurity of low-income families and youth. In 2022, four EFNEP educators were trained in Vance, Warren, Martin, Guilford, and Durham counties. The educators conducted programs to educate community members on the importance of nutrition. In 2022, the EFNEP programs reached 84 adults and 199 individuals from their families as well as 800 youth through direct programming. Participants overwhelmingly reported improved knowledge about nutrition and the need for exercise and most said they planned to change their diets by eating more fruits and leafy green vegetables and limiting their soda intake. By providing nutrition education and resources to low-income families, EFNEP helps improve the overall health and well-being of these families. This can include reducing obesity and other diet-related chronic diseases, as well as increasing food security. Additionally, by teaching families how to make healthier food choices and stretch their food budgets, EFNEP can help reduce poverty and improve economic stability for low-income families.

Annual Result: Lifelong Improvements through Fitness Together (LIFT)

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

One-third of adults 65 and older will fall each year, a fact y, 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 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.

Only 17 percent of older adults meet the required exercise recommendations, but older adults need to be as active as their physical conditions allow. Being inactive can lead to lost mobility, a higher risk for obesity, and impaired or reduced strength and balance.

Adults should move more and sit less throughout the day. For substantial health benefits, adults should do at least 150 to 300 minutes a week of moderate-intensity or 75 to 150 minutes a week of vigorous-intensity aerobic physical activity. Adults should also do muscle-strengthening activities of moderate or greater intensity that involve all major muscle groups on two or more days a week. Adding to the problem, less than 30% of older adults meet the dietary guidelines for fruit and vegetable consumption. Older adults with healthy diets who meet their physical activity recommendations are more likely to be able to age in place. According to the North Carolina Physical Activity and Obesity profile, 26.4% of North Carolina's adults reported not participating in any physical activity during the past month.

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.

Lifelong Improvements through Fitness Together (L.I.F.T.) is a group-based strength training program implemented to address the aforementioned challenge of physical fitness and health in older adults. L.I.F.T. sessions are held twice a week for one hour over eight weeks and include an active warm-up, eight core strength training exercises, and a cool down. The program also includes basic nutrition information emphasizing increased fruit and vegetable intake. This helps participants exercise as well as gain nutritional knowledge.

The SNAP-Ed Coordinator has trained agents across 12 counties on the L.I.F.T. curriculum. The agents conducted a total of 16 L.I.F.T. classes.

The classes consist of the following:

- 8 core strength training exercises.
- Group dynamics to faciliate communication andto help form relationships.
- Promotion of increased fruit and vegetable consumption.
- Encouragement to get out and move—150 minutes of moderate activity or 75 minutes of vigorous activity each week

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

Weightlifting exercise is essential for adults because it helps build and maintain muscle mass, which in turn helps to improve overall strength, fitness, and bone density. Additionally, weightlifting can improve balance and stability and help decrease the risk of chronic diseases such as diabetes, heart disease, and certain cancers. It can also help improve mental health and mood.

The Swain County Extension agent offered L.I.F.T., and participants completed L.I.F.T. pre- and post-evaluations. The results indicated that overall, the participants were more comfortable using hand and ankle weights and felt confident they could correctly utilize the equipment on their own while exercising at home. Participants reported feeling stronger and being able to increase the weight of their dumbbells. Participants also reported feeling stronger in their core and more confident when doing chair squats. Results also indicated that each participant improved their balance by an average of 2.25 seconds. After completing the eight sessions, five participants reported feeling confident they could engage in moderate physical activity for 30 minutes for two more days each week.

The Stanly County Family and Consumer Sciences (FCS) agent facilitated the L.I.F.T. program with five participants. Participants enjoyed the program so much that they agreed to participate in a L.I.F.T. virtual study with the agent directly after to continue to work on their goals. After completing two rounds of L.I.F.T., all participants increased their weekly physical activity, strength, and confidence in strength training. One participant shared that she lost over 12 pounds due to the program. Other participants noted, "Our lift instructor is the best. She's encouraging, challenging, and always made sure we

were doing it correctly." Others said, “Loved this class!" and "It is a great program, and (FCS Agent) Hayley Cowell is an excellent teacher." The FCS agent plans to team up with fellow FCS Agents in 2023 to offer another L.I.F.T. Program for Stanly County and beyond.

The Montgomery County nutrition educator and the FCS agent partnered with the Community Connector with Better Together Montgomery to implement the L.I.F.T. program in the Peabody Community twice a week for eight weeks. The program included a pre-and-post-assessment of physical abilities. Class sessions included exercise and nutritional education, as well as group interactions. Participants were asked to track their physical activity and fruit and vegetable consumption for the duration of the program. The program's primary goals are to improve dietary intake, increase strength, flexibility, and balance, and help senior adults age in place. Twenty-five participants enrolled in the program, and 10 graduated by attending at least nine of the 16 sessions. Functional fitness testing demonstrated that class averages improved in all areas (strength, flexibility, and balance). Chair stands, bicep curls, and the step test all measure strength. The class average for chair stands was 7.8 and 10.1 (pre and post); for bicep curls, it was 17 and 26.9 pre-to-post; and the step test measured 55.7 (pre) and 74.1 (post). The overall balance average increased from 39.93 seconds to 43.69 seconds. Flexibility was measured by the sit and reach activity and the back scratch, demonstrating improvements. Furthermore, results of Try Healthy evaluations indicated improvements in fruit consumption and decreases in sugar-sweetened beverage consumption. Participants reported increases in the number of days they exercised for at least 30 minutes. One participant stated that the program gave her the confidence to keep moving and improve her health. "I feel healthier and can do more stuff by myself without being scared I'm gonna get hurt."

The FCS agent in Scotland County partnered with the county activities director to offer the L.I.F.T. Program to eight residents. Due to the participants' health issues and physical limitations, a modified L.I.F.T. program was provided. One participant shared that before L.I.F.T., she was completely walker dependent, unable to dress alone, had poor balance, and low energy. She had hip surgery six months prior and set a L.I.F.T. goal for herself to become less reliant on her walker and more independent. Since participating in L.I.F.T, she has increased her stamina and energy, improved her range of motion, can touch her toes, and her balance has improved. She can do more things for herself, such as dress, fix her hair, put on socks, tie shoes, and no longer use her walker in her room. One of her most significant accomplishments came with the wide-leg squats. She could not do any of these during the pre-assessment, but by the end of the eight weeks, she could complete 12.

The Scotland County FCS agent and the county's Parks & Recreation Division partnered to offer the L.I.F.T. program to 24 residents. The two L.I.F.T. one-hour weekly sessions consisted of a warm-up, three sets of the eight core exercises, and a cool-down. Participants reported the following improvements following program completion: Participant 1: Always an avid gardener; she noticed trouble getting up from the ground or floor. She was afraid she would have to give up her hobby. She saw a loss of muscle mass and knew she had to make some health changes. Her father spent his last years in a wheelchair, and she didn't want that to happen to her. The L.I.F.T. class gave her a better range of motion and more stamina; she can now get up and down without any problems. In addition, she benefited mentally and socially as she gained many new friends.

Participant 2: She had torn a ligament in her right foot. Since she did not play any sports, the doctor recommended physical therapy and foot/ankle exercises. Although she saw some slight improvement, she was still experiencing pain, and her balance was not good. Since incorporating L.I.F.T., she says her foot and ankle are much stronger, her pain is gone, and her balance has improved dramatically. Participant 3: She was not exercising at all, and per her doctor's recommendation, she signed up for some health and wellness classes. The participant has several health issues, including diabetes, which could improve with a healthier lifestyle. Since incorporating L.I.F.T., she has noticed she has more mobility, increased energy, increased range of motion, more confidence, and feels more connected. She stated she is proud of herself for signing up for L.I.F.T.

Participant 4: The participant shared that she suffered from back and throbbing shoulder pain that decreased her ability to participate in many activities. Since beginning L.I.F.T. classes, she is no longer experiencing any pain in her back and shoulder.

Participant 5: The participant shared that she previously had many problems with hip and back pain; however, since joining L.I.F.T., she is no longer experiencing pain.

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

Reducing chronic disease is essential to society because it can improve overall health and well-being and can also help decrease healthcare costs. Chronic diseases, such as heart disease, diabetes, and cancer, are the leading causes of death and disability worldwide. They are also responsible for a large portion of healthcare spending and can put a significant financial burden on individuals, families, and the healthcare system. By reducing the prevalence of chronic diseases, society can improve overall health outcomes and reduce healthcare costs, which ultimately benefits everyone. Reducing chronic disease can also improve productivity and quality of life for individuals and 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.

Older adults need to stay as active as their physical conditions allow, since inactivity can lead to loss of strength and mobility, impaired balance, obesity, and falls that leave them unable to care for themselves. Adding to the problem, less than 30% of older adults meet the dietary guidelines for fruit and vegetable consumption. Lifelong Improvements through Fitness Together (L.I.F.T.) is a group-based strength training program that includes a warmup, eight core strength building exercises and a cool down. The program also includes basic nutrition information emphasizing increased fruit and vegetable intake. In 2022, Extension agents serving 12 counties conducted 16 L.I.F.T courses, with each course consisting of 16 one-hour sessions presented over eight weeks. Participants reported increased strength and flexibility and improved balance through L.I.F.T. The program can help reduce the prevalence of chronic diseases, decrease strain on the healthcare system, and help older adults stay independent and able to age in place.

Annual Result: Nutrition

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

Obesity has been linked to heart disease, stroke, type 2 diabetes, and certain types of cancer. Estimated medical costs for obese individuals are $1,429 higher than those at an average weight. Increasing levels of obesity are associated with reduced quality of life, impacting not just the individuals but their family, friends, and the environment to which they are exposed. Factors such as eating patterns, physical activity levels, genetics, sleep, and other social determinants of health contribute to the rising rates of obesity. In rural areas, access to healthy fruits and vegetables, limited nutrition education, and low incomes are critical causes of the high rates of obesity.

Despite food safety communication efforts by many sectors, foodborne illness also remains a significant health issue in North Carolina and across the U.S. The Centers for Disease Control and Prevention (CDC) estimates as many as 48 million cases of foodborne illness occur annually, leaving 128,000 people hospitalized and causing 3,000 deaths. Most foodborne illness is caused by 31 major identified pathogens, including norovirus, salmonella, and listeria. Regardless of the cause, foodborne illness costs society an estimated $152 billion annually. 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. When preserving, it is essential to employ evidence-based, research-tested strategies and methods to ensure the safest products.

COVID has brought newfound zeal to home foods preservation. In a 2020 study by Haynes-Maslow (Haynes-Maslow et al., 2020) among 383 North Carolinians, 24% wanted advice on food preservation such as canning, freezing, and drying foods. This year, 36 dial gauge pressure canning lids were tested, whereas in years past, less than 20 lids were tested, indicating a rise in interest in canning. Home food preservation, when done incorrectly, can be detrimental. According to a study conducted by the National Center for Home Foods Preservation, over half of the surveyed participants (n=135) obtain their canning information from a friend or relative whereas only 2% gain their information from an Extension publication.

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 2022, Family and Consumer Science (FCS) agents and nutrition educators in Montgomery, Stanly, and Alexander Counties conducted programming for youth and adults that focused on reducing chronic diseases, food insecurity, food safety, and nutrition.

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

Across all nutrition programs, 425 adult participants increased their consumption of fruits and vegetables, and 363 increased their physical activity. Sixty adult participants indicated that they now consume less sodium, while 54 stated they consume less sugar. Also, 185 children participated in childcare programs focused on food systems, gardens, and cooking. Overall, 892 participants increased their knowledge of how to prepare foods, including home preservation techniques. Additionally, 845 participants increased their knowledge of safe food handling, preservation, or preparation practices. One-hundred seventy-three participants stated they would begin using local foods when cooking and preserving foods.

In 2022, the FCS agent in Stanly County earned the esteemed title of Safe Plates Distinguished Educator in Home Food Preservation. This title recognizes her advancement in home food preservation programming, which means she serves a trusted vital role with the NC Extension Safe Plates Food Safety team, helping to propel and strengthen food safety programming efforts across the state. The agent has established multiple partnerships to co-teach and mentor other FCS agents in her district to ensure others have the confidence to teach more difficult food safety concepts. Because of this, she has impacted the state's home food preservation programming. We have seen the agent's exemplary teaching skills, enthusiasm for the topic, and compassion towards her community members while she is disseminating the science behind food safety information. As a distinguished educator in 2022, she was able to answer questions via email from her fellow FCS agents, assist with two home food preservation classes in Lee County, and teach a home food preservation class to students enrolled in the Home Food Production course at NC State University. She will continue to offer her expertise and assistance in home food preservation to others across the state in the coming years.

When offering preservation classes, one of the most recurring challenges in Alexander County is determining a format most conducive to Alexander County citizens. The primary audience for this type of program is individuals 18 and older, but time is a significant constraint for this group. Alexander and Iredell counties implemented a home foods preservation boot camp to accommodate the time constraints. The goal was to allow individuals to gain as much information on as possible on a variety of home food preservation practices rather than just one aspect. These included boiling water bath canning, pressure canning, pickling, and fermenting, and drying. The day-long (6-hour) class allowed participants to learn about each process and practice the preservation technique with agents and among peers. Five participants attended the boot camp. In a conversation with the participants, two stated that they wanted to learn more about preservation because they own a farm, raise lots of fruits and vegetables, and want to preserve their extra produce properly. Another participant stated that her grandmother practiced canning, and the art was lost to her. Two additional participants shared that they wanted to know how to store food for future use. Although the numbers were low, the results were positive. All participants increased their knowledge of all the different food preservation methods and planned to utilize one or more of these skills in their homes. Behavioral change approaches such as the PRECEDE/PROCEED model illustrate the importance of behavior changes through self-efficacy. By working alongside the participants and enabling them to gain hands-on experience that builds their confidence, participants become more willing to preserve food on their own. One participant shared, "I was always scared to pressure can by myself in fear of the canner exploding, but this [boot camp] has made me feel more comfortable to do this at home." Another shared that she "liked that so much was covered and offered on time, not on a workday."

Studies show that two-thirds of all chronic diseases can be prevented by lifestyle change, specifically with diet and exercise. To help address the obesity epidemic in Alexander County, the Med instead of Meds series was implemented for nine participants. All participants were female, ages 45-65 but over half indicated an underlying health condition they wished to manage. Med instead of Meds consists ofsix, one-hour sessions.. Each session covers key components of Mediterranean eating patterns, the only eating pattern recommended by the USDA Dietary Patterns. Topics covered included foods to focus on, mindfulness, proper food storage and safety, ways to eat on a budget, and a taste test component from one of the recommended recipes. As a result of the program, all participants gained knowledge and confidence in the Mediterranean eating pattern, mindful eating, strategies for eating the Med way, and strategies to implement the Med way of eating. Based on post-evaluation, 100% of the participants use olive oil more often in cooking and preparing food; 80% serve and eat healthy protein more often and serve, eat, and drink highly processed foods less often. Additionally, 80% serve and eat whole grains more often, and serve and eat nuts and seeds more often. Over 60% serve and eat vegetables and fruit more often. After the series, one participant said, "Just wanted to share with you that I found out today I have lowered my cholesterol by 26 points! I'm so pleased, and my doctor was as well. I told him about your class. I have incorporated more vegetables and fish. I still love my desserts but read labels more diligently. Glucose was down a few points, too, not that it was a problem before. Thank you for your help! I hope you will run the class again so others can benefit." Another participant shared that in working three jobs, the meals were easy to make.

The nutrition program assistant in Stanly County used The OrganWise Guys, a research-based program, to teach kindergarteners and first graders at Heritage Classical Academy. For students to understand the importance of organs in their bodies, each lesson used puppets to represent the lungs, heart, kidneys, etc., for a visual appeal when discussing eating healthy, staying physically active, and the importance of staying hydrated. Each of the four lessons had a story booklet that focused on the following:

1. The importance of keeping your teeth healthy and clean.

2. Identifying healthy food items when going grocery shopping.

3. Increasing physical activity while reviewing over-counting skills.

4. Making a connection between caring for our organs as if they were pets in the home.

Understanding that we must prioritize our health just as we do playing sports, doing homework, and showing up for class each day will make a difference for these children in the future. Pre and post surveys were collected to show the effectiveness of the OrganWise Guys program. The survey results showed a 100% increase in knowledge from each of the 25 participants when comparing outcomes from the first day of class to the last day. They included improvements in identifying healthy foods versus unhealthy foods and knowing what qualifies as physical activity. After each lesson, the program assistant asked questions about the topic to see what each student learned. Most students gave examples of ways they are living healthier while reflecting on how their organs appreciate them for making those small health changes. Many of the students gave verbal feedback on how effective the program was for them, such as "I went grocery shopping with my family and bought apples," "I played tag with my best friend at recess," and "I like when you come to teach us about healthy foods." The teachers also stated, "the students looked forward to this program each week, and they thoroughly enjoyed the puppets and the stories being read." Once the program was completed, the program assistant received thank you notes from each student explaining their favorite OrganWise Guy and how they plan to keep that specific organ healthy! The nutrition program assistant plans to offer nutrition education programs for youth within the county continuously.

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

When individuals are healthy, healthcare costs are lower. Furthermore, when people buy locally, they support the sustainability of their community. All nutrition programs benefit the individual, their community, and the larger community by improving health outcomes and opportunities for knowledge gain and behavior change.

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.

Try Healthy magazine, distributed in the summer of 2022, is the perfect resource for families looking to stretch their food dollars and make healthier meals. Try Healthy contains:

- Simple, easy-to-follow instructions for creating healthy meals.

- Nutritional information.

- Kitchen science information.

- Tips for stretching food budgets.

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.

Obesity is a major problem in limited-resource communities, often leading to other chronic diseases, higher medical costs, and reduced quality of life. Foodborne illness also impacts limited-resource North Carolinians, and the increase in home gardening and home food preservation during the pandemic makes the need for food safety education even more important. Extension agents in three North Carolina counties addressed these overlapping problems through programs aimed at increasing fruit and vegetable consumption, and various types of food preservation, including canning, pickling, fermenting, and drying. The programs taught adults and children to improve their diets, informed participants about the benefits of eating locally grown foods, and demonstrated safe food preservation techniques. The goal was to help communities become healthier, lower their overall healthcare costs, and encourage buying locally to sustain the local community.

Annual Result: Supplemental Nutrition Assistance Program-Education (SNAP-Ed) and Healthy Habits

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

Childhood obesity has more than doubled in children and quadrupled in adolescents in the past 30 years. Obese youth are more likely to have risk factors for cardiovascular diseases, such as high cholesterol or high blood pressure. A healthy diet is the foundation for overall health and well-being. While all segments of the U.S. population are affected by obesity, low-income people can be especially vulnerable due to the additional risk factors associated with inadequate resources and under-resourced 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 Supplemental Nutrition Assistance Program- Education (SNAP-ED) is a nutrition education program funded by the United States Department of Agriculture (USDA). SNAP-ED helps people with limited resources make healthier food choices and increase physical activity. The program works with community partners to promote nutrition education and physical activity to SNAP recipients. SNAP-ED focuses on key nutrition strategies, such as consuming more fruits and vegetables, making healthier snacks and meals, and reducing sugar-sweetened beverages. It also promotes physical activity, such as walking, biking, and playing active games. SNAP-ED also supports community-based policies and environmental changes to help people with limited resources make healthy choices easier.

Increasing Try Healthy PSE and social marketing outreach was an important goal in 2022. We created bulletin boards, social media ads, and public service announcements (PSAs) that focused on increasing consumption of fruits and vegetables, physical activity, drinking water and low-fat milk, and promoting breastfeeding, which can all lead to healthier lifestyles. Partnering with Aggie Source and Guilford Technical Community College (Tritain Link) Food Bank enabled us to enhance the food bank environment to encourage healthier food options for people in need. Marketing made the public aware of the importance of making healthier choices for themselves and their families. The outreach was critical in helping individuals and families make healthier and more informed lifestyle choices. Because of this effort, we achieved more than 6 million impressions through our social media and marketing efforts.

The Healthy Habits program is a supplemental program to SNAP-Ed. It works with schools and community partners to implement an eight-hour series that promotes healthy living for youth and their families.

In 2021-2022 the N.C. A&T 4-H Healthy Habits program trained five teen ambassadors and reached 2,476 youth using the Go, Glow, Grow, and Teen Cuisine curricula. Nutrition classes were conducted in Warren, Vance, Montgomery, Guilford, Pitt, Stanly, and Forsyth counties.

Teen ambassadors and agents worked together to:

- Conduct nutrition education programming on dietary guidelines, including promoting certain foods and nutrients to increase, such as vegetables, fruits, and foods with more potassium, and recommending limitations on less healthy foods and components, such as sodium, solid fats, and foods and beverages with added sugar.

- Integrate nutrition into ongoing physical activity group sessions.

- Implement classes to build fundamental skills such as cooking.

- Distribute family-oriented newsletters that include child/parent activities and recipes.

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

In 2022, out of 4,092 children, 42% who t participated in Glow, Grow Go, Speedway to Healthy, and the L.I.F.T. program increased their knowledge about the benefits of physical activity and strategies for reducing inactivity. Additionally, 50% demonstrated an increased knowledge of healthy food choices and the benefits resulting from daily diet improvements. In addition, 45% of children participating in Teen Cuisine improved their dietary habits, while 40% improved their physical activity. Across the Eat Smart, Live Strong, Teen Cuisine, L.I.F.T., Glow, Grow and Go programs, 56% of children increased their fruit and vegetable intake. With the Eat Smart Live Strong program, 39% of participants reported making better choices in food resource management practices. 73% of participants with active partnerships in SNAP-Ed qualified sites or organizations exchange information and identify and implement mutually reinforcing activities that will contribute to adopting one or more organizational changes or new policies. Lastly, 43% of program participants reported seeing our bus ad or social media campaign encouraging them to choose healthy food.

In 2022, out of 2,515 children participating in Healthy Habits programming, 93% reported always or usually paying attention to how much fruit and vegetables they eat each day. Additionally, 72% said they gave their family ideas for healthy meals or snacks, and 88% reported they plan to prepare healthy meals or snacks for their family. Survey results found that 91% of the youth said they plan to drink the daily recommended amount of water, and 91% reported they learned how to make healthy food choices.

To decrease the risk of obesity and associated complications, the Stanly County nutrition program assistant brought the education to the Stanly County Senior Center. The research-based program taught was Eat Smart, Live Strong, a four-week program for individuals 60 years and older that focuses on two fundamental behavior changes: consuming 3 ½ cups of fruits and vegetables daily and getting 30 minutes of physical activity most days. This curriculum centers on goal setting, challenges, solutions, ways to make meals colorful and healthy, and tips on spending less while eating smarter. Warm-up and cool-down exercises were also provided as a guide for at-home workouts. Food demonstrations and a cost-affordable recipe, and handouts relating to the weekly topics were included with each lesson. There were 11 participants in the program. Pre- and post-surveys were collected to see how often each participant was consuming fruits and vegetables, drinking milk, budgeting, reading food labels, and exercising. The survey results showed that 100% of the participants already exercised most days, as many attended the chair yoga hosted at the senior center. By the end of the program, a group of participants stated that they started walking together to hold each other accountable for their daily exercise. Fruit and vegetable consumption varied based on whether or not they ate them often or daily. All participants said they use coupons while shopping and cook their meals at home most days. Many explained that they have started eating more fruits and vegetables as a snack rather than high-sodium and sugary food items. Some participants modified the take-home recipes to include more fruits and vegetables to their liking. The verbal feedback included, "I added blueberries, seeds, nuts, carrots, and cucumbers to the strawberry spinach salad recipe," and "I substituted the dill relish for the black olives in the Mediterranean tuna salad. “I added sweet potatoes and bell peppers to the black bean quesadilla." Each participant expressed how grateful they were to have received a food demonstration along with recipes, exercise handouts, and lessons that focused solely on the barriers that the older adult population may face regarding healthy eating and staying physically active.

The nutrition educator in Montgomery County implemented the Go, Glow, Grow nutrition curriculum at Mt. Gilead, Candor, and Green Ridge Elementary Schools, reaching 17 preschoolers, 58 kindergarteners, and 10 teachers and assistants. Based on the USDA's MyPlate, Go, Glow, Grow simplifies MyPlate for preschoolers and kindergartners. It is divided into three sections labeled Go, Glow, and Grow. Each section corresponds to the effects these food groups have on the body. Go foods contain the grains group,-, foods that provide the body with energy. Glow foods include vegetables and fruits that supply the body with vitamins and minerals. Grow foods contain protein and dairy that help the body grow and develop strong bones and muscles.

Through this curriculum, preschoolers and kindergartners learned to make the connection between eating healthy foods and beginning to live healthier lives. All six lessons were delivered to each of the five classrooms at the three schools. All teachers/staff indicated that the North Carolina Foundations for Early Learning and Development standards were fully met through the Go, Glow, Grow curriculum. Furthermore, all teachers reported that their students looked forward to the lessons. After completing the program, 10 of 10 teachers stated that their students now know what foods are included in the categories of Go, Glow, and Grow; 8 of 10 teachers indicated talking more about healthy options in their classroom and 8 of 10 reported that their students are more willing to try fruits and vegetables. One teacher reported the following success, "Students now talk to us about what kinds of foods they are eating on their breakfast and lunch trays." A student said, "she did not like strawberries." When Ms. Elizabeth brought bagels with strawberry cream cheese and fresh strawberries, the little girl tried them and loved them! At the end of the program, one student came up to the nutrition educator and asked her if she was coming back to teach about healthy foods and healthy living because she loved it when she came! Some children even mentioned to their parents at pick-up how they tried something new and were excited about it even if they didn't like it!

The Vance County 4-H agent partnered with the Warren County 4-H WAY program and EFNEP (Expanded Food and Nutrition Education Program) to present a six-session program from 9 a.m. to 4 p.m. across one week, providing 20y 6th-12th grades students with skills about food and nutrition based on the Teen Cuisine Curriculum. The students identified as African American (14), Latino (4), and mixed or two/more races (2). They joined yoga sessions to increase mental health and wellness of body, mind, and soul. 80% of the youth increased the frequency of their physical activity during the week (activities in which they increased their heart rates, and they breathed hard most of the time), and 75% put foods back in the refrigerator more often within two hours. 67% of youth increased the number of days they were physically active for at least 1 hour, 50% drank sweetened drinks (e.g., soda, sports drinks, energy drinks) less frequently, and 50% were more confident using measuring cups and measuring spoons. 75% of the youths spent fewer hours watching TV or movies, playing electronic games, or using a computer for something that is not schoolwork. 54% ate vegetables more frequently, and 46% ate fruit more regularly.

The EFNEP educator in Vance County partnered with Clark Street Boys & Girls Club and recruited 60 K-10 students to share the experience of learning healthy daily eating alternatives to prevent obesity and other chronic diseases. The predominantly African American students (82%) participated in the two-week, six-session Show Me Nutrition program for nine hours. Healthy recipes for an appetizer, entree, and dessert were taught throughout the program, utilizing each food group from MyPlate and the standard program activities. After completing nutrition education lessons, survey results showed that youth improved in the following ways: 64% of youth ate whole grains more frequently, 64% of youth increased the number of days they were physically active for at least one hour, 64% of youth ate fruit more regularly, 57% of youth washed their hands more often before eating, 57% of youth made healthier food choices more often when eating out. After completing nutrition education lessons, survey results show that youth improved in the following ways:

- 89% improved their ability to identify when to wash their hands before eating.
- 78% improved their ability to identify dairy foods.
- 63% improved their ability to identify fruits.
- 50% improved their ability to identify vegetables.
- 33% improved their ability to identify healthy snacks.

After completing nutrition education lessons, survey results show that youth improved in the following ways:

- 50% improvement in decreasing the frequency of drinking soda in the past week.

- 45% improvement in the duration of physical activities.
- 40% improvement in the frequency of reading nutrition facts labels.
- 40% improvement in decreasing the frequency of drinking fruit-flavored and sports drinks in the past week.
- 35% improvement in the frequency of tasting new foods.

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

SNAP-ED helps reduce health disparities by providing nutrition education to low-income individuals and families who may otherwise not have the resources to access nutrition information. It also helps improve the community's overall health by providing nutrition education and resources to those who may not have access to them. Additionally, SNAP-ED helps to reduce healthcare costs for everyone by helping to prevent chronic diseases associated with poor nutrition, such as obesity and type 2 diabetes. Lastly, SNAP-ED helps promote healthy food consumption, which can lead to improved food security for all community members.

Nutrition education empowers children with the knowledge and skills to choose healthy foods and beverages selecting healthier food options is essential to keeping current and future generations healthy across the lifespan. A healthy diet helps children grow and develop properly and reduces their risk of developing chronic diseases as an adult.

Impact Statement (Optional)

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The Supplemental Nutrition Assistance Program- Education (SNAP-ED) is a nutrition education program funded by the United States Department of Agriculture (USDA). SNAP-ED helps people with limited resources make healthier food choices and increase physical activity. The program works with community partners to promote nutrition education and physical activity to SNAP recipients. N.C. A&T offers the adult SNAP-ED program called Try Healthy and a similar program aimed at youth called Healthy Habits. Some educational programs offered through SNAP-ED include Eat Smart, Live Strong (for adults), Teen Cuisine (for teenagers), and Glow, Grow, Go (for younger children). The ultimate aim of the program is to help low-income people reduce their risks for obesity and the health problems related to obesity, including cardiovascular disease and diabetes.

Critical Issue

Enriching Youth, Family & Community Well-Being

4-H Youth Development

Project Director

Meredith Weinstein

Organization

North Carolina State University

Accession Number

7000171

Annual Result: 4-H Youth Development

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 (22% of the state's population). One quarter of those youth live in families that receive public assistance, and twenty percent live in poverty. According to a National 4?H Council commissioned survey to explore teens' perceptions and experiences around mental health, 81% of teens say mental health is a significant issue for young people in the U.S., and 64% of teens believe that the experience of COVID-19 will have a lasting impact on their

generation's mental health. Today, 7 in 10 teens have experienced struggles with mental health; 55% of teens say they've experienced anxiety, 45% excessive stress, and 43% depression. Youth need supportive out of school programs with foundations in positive youth development for successful growth.

In addition, youth in North Carolina graduate at a rate of 86.3, and 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. Educators often report that students lack understanding and appreciation of the sciences. This creates a continual need to provide students and educators with educational enrichment activities.

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 2022 Extension offered a broad range of in-person and virtual 4-H educational programming to help youth develop life skills that will prepare them for future success. These programs focused on civic engagement, healthy living, and STEM, and they included activities such as day camps and overnight camps, clubs, in-school and afterschool enrichment activities, hands-on projects, service activities, and online educational programs.

- NC State Extension agents used **social media and websites** to provide educational information to nearly 2 million youth.

- Extension 4-H agents reached 6 million individuals through various **outreach events** such as fairs, festivals, ag expos, livestock shows, and other community events.

- 3,400 **teachers were trained** on how to deliver 4-H STEM curriculum, and Extension Forestry facilitated 21 NC Project Learning Tree program workshops across the state, reaching 383 formal and nonformal educators.

- 84,000 hours were donated by **4-H volunteers**, providing opportunities for youth to work and learn in partnership with caring adults.

- 188,245 youth in North Carolina participated in one or more 4-H youth development programs during 2022. **4-H clubs** had 19,585 members. 1,149 youth participated in **overnight camping** programs, 137,415 youth participated in **school enrichment programs**, 46,788 youth participated in **special interest programs**.

Families today are farther removed from agriculture than they have ever been, and many youth are learning inaccurate information about agriculture through social media. To address this problem, Pasquotank County 4-H and local partners hosted a **Wake Up to Agriculture Day**. This educational program reached all 352 third grade students in Pasquotank County public schools, allowing them to visit interactive stations and learn about the importance of agriculture in their daily lives and agricultural careers available for them to explore as adults. Based on the success of this program, planning for next year's event has already begun, with plans to explore expanding into private schools. An **Agriculture Awareness Day** was hosted by Extension in Wilkes County, with the help of students from East Wilkes High School, Wilkes Early College High School, and Wilkes Community College along with Master Gardener and other community volunteers, to educate third grade students about North Carolina agriculture. Approximately 450 third grade students attended the event. Students were excited to learn about the livestock and commodities produced in North Carolina. The hands-on stations gave students the opportunity to interact with livestock and other products that they may not have ever seen. Based on the evaluations, teachers and students alike found this event worthwhile and would attend again in the future. **Through STEM programs such as these, youth in North Carolina participate in hands-on learning experiences and increase their knowledge of agricultural literacy and where their food comes from to prepare for future success.**

Youth across NC also participated in **livestock, poultry, and small animal shows and judging; 4-H projects; and clubs** among many other animal science programs. Statewide, Extension youth animal programs had over 26,000 youth participants. By participating in showing livestock and other events, youth learned communication skills, work ethic, responsibility, and sportsmanship. These opportunities enabled the participants to meet and build relationships with youth with similar interests. The **NC 4-H Horse Program** has an estimated 5,400 registered youth participants, 75 horse program-focused clubs, and 230 registered volunteer adult leaders. The program hosted 50 different stakeholder interactions this year through **events, training, contests, and activities**, with an approximate total of 500 contact hours reaching 7,174 participants. Nine state

contests were held, some virtual, some in person, and 909 youth participated in regional and national competitions. Equine specialists created 28 **videos** viewed over 1,600 times. The horse programs' 450 **social media** posts reached over 300,000 people. The Extension **Equine Husbandry website** reached 10,000 individuals over the course of the year. The NC 4-H Horse Program helps youth develop leadership abilities, build character, and assume citizenship responsibilities. **Involving youth in 4-H animal programs helped introduce and inspire youth to consider career opportunities in agriculture.**

In Catawba County, 4-H partnered with STEM West and the Catawba County library system to offer the 10-week **Lego Robotics program** to 81 youth in grades 2–4. Based on youth and parent evaluations, 55% of participants enjoyed hearing others ideas and learning how the robotics worked, and 81% of the parents reported that their children are more interested in STEM after attending the program and they saw an improvement in their child's ability to solve problems and work with others. In Cabarrus County, 4-H partnered with afterschool sites and Cabarrus and Kannapolis schools to deliver the **National 4-H STEM Challenge: Explorers of the Deep**. This program developed observational and critical thinking skills while empowering students to explore the relationship that all human beings have with the ocean, regardless of where they live. Four trainings were held to educate teachers with the 4-H curriculum kit, and grant funding from the Cabarrus 4-H Foundation supplied STEM Challenge kits to each participating classroom. Thanks to these efforts, over 7,000 students from across Cabarrus County participated in the STEM Challenge. **Engaging youth in STEM activities is just part of how we are growing future scientists.**

In Surry County, 4-H partnered with local schools to provide 149 youth in grades 6–8 with lessons on **soft professional skills**. Each set of lessons was tailored to learning objectives for each grade, with the aim to help students learn new soft skills and build on previous ones as they progress through their education. Surveyed participants reported gaining new life skills from the program, including improved self-confidence, self-motivation, organization, leadership, communication, and goal setting 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.**

In 2022, Extension continued expansion of the **#PassTheMicYouth** program to encourage youth development of skills in civic engagement, critical thinking, and leadership. The program provides youth with **training and equipment to launch 7 podcasts**. The program website attracted over 20,000 visits and nearly 2,000 social media followers. In Wake County, 4-H provided 9 youth with a weeklong summer experience at the #PassTheMic Camp, hosted at NC State and the NC Arboretum. Through collaborations with community partners, local artists, and activists, youth created art pieces, professionally recorded podcast trailers, wrote spoken word poems, and shared their voices with community members in a showcase. Several of these youth have since continued to collaborate on podcast projects and have joined 4-H clubs. **NC State Extension is preparing youth to be future leaders.**

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

Expanding on a **school garden project** that began in 2021, Bladen County Extension delivered a 7-session program both in person and online over the course of 14 weeks, guiding 269 students through the process of planning their garden and teaching them about various garden design factors, such as sun exposure and water availability. Extension agents created a Google site containing pre-recorded garden updates from an Extension test garden; self-directed supplemental education content focusing on the plant life cycle, garden management, MyPlate and other nutrition concepts; and printable classroom worksheets to help students plant, maintain, and harvest their school gardens. Evaluations indicate that over 98% of students learned more about the plant life cycle, 99% learned how to choose a healthy diet using MyPlate as a guide, 96% learned how to read nutrition facts labels, and over 94% feel confident or very confident in their ability to plant a garden at home. **Statewide, 9,025 youth grew food by participating in Extension organized school or home garden programs.**

New Hanover County Schools (NHCS) generates excessive waste that could be diverted from the County Landfill. Cooperative Extension developed a pilot program in partnership with local partners to divert landfilled food waste through composting. The Garbage to Gardens program (G2G) intends to develop **food composting** at scale across NHC. At the two G2G pilot schools, 75%-90% of a school's average daily cafeteria waste volume was diverted from the landfill. 212 students at DC Virgo Academy composted 15,360 pounds saving 15 cubic yards of landfill space. Winter Park Elementary School composted 2,240 pounds on Waste Free Wednesdays, saving 2 cubic yards of landfill space. **If all 52 public and charter schools in NHC participate in G2G for one year, over 769,000 pounds of food waste could be composted, saving over 719 cubic yards of landfill space. Increased recycling rates are a direct impact of this program.** In 2022, DC Virgo recycled 5000 gallons of plastic and Styrofoam. Students at both schools received compost educational programming this year. Going forward, G2G will provide curriculum correlated across grade levels to support the learning objectives of the NC Standard Course of Study as well as developing student leadership opportunities. **4-H programs teach youth to be engaged in the world around them and provide them opportunities to take action to protect the environment.**

In Currituck County, Extension administers the **Community Service and Restitution (CSR) Program**, assisting young women and men in completing court-ordered community service hours and paying any required restitution. Placing youths in local businesses and organizations to complete community service has become increasingly difficult over the years because of insurance requirements, required supervision, and most recently, the COVID-19 pandemic. To tackle this problem, Currituck County Extension began building a **community raised bed garden** through the CSR program, allowing youth to complete their hours while learning how to plant, tend, and harvest vegetables throughout the growing season. The most recent addition is a beekeeping program with 3 hives, with plans to expand by 3 more. In 2022, youth in the CSR program grew over 600 pounds of fresh vegetables for the Currituck County Senior Center and the Lower Currituck Food Bank. **NC Extension provides hands-on, experiential learning opportunities that help youth enjoy healthy lifestyles and avoid high-risk behaviors while contributing to their communities and developing knowledge of horticulture.**

To help local youth develop healthy coping mechanisms, Madison County 4-H teamed up with Madison Middle School health educators to incorporate a **positive stress management program** into health classes. Students were encouraged to use a positive, solution-focused approach to managing stress while learning to identify specific sources of stress and joy in their lives and develop tailored coping strategies. Through experiential activities, youth compared the physical, psychological, and social effects of healthy coping strategies with those of unhealthy strategies. Thanks to this program, 330 middle school students practiced healthy stress management strategies, including gratitude, deep breathing, and stretching. They also participated in group discussions and learned about mental health support resources. According to the teachers, this is one of the most memorable classes in terms of equipping youth with positive life management strategies and increasing youth understanding of the dangers of substance abuse. **NC State's 4-H programs supported students' mental health through stress management and mindfulness activities.**

in New Hanover County there are two alternative schools serving K – 12 students with behavioral issues. The **Ability Garden** provides gardening activities as a **therapeutic intervention** at both schools. Our activities are designed to build self-confidence, teamwork, leadership and promote delayed gratification while introducing basic gardening and environmental concepts. In the pollinator garden installed last year, there is a large amount of dollar weed that needs constant attention, surprisingly this is the most successful activity this year with the students. They work together in self composed teams to see which team to pull the longest root, our record to date is 6' 5." The teachers were amazed and conveyed that it was the first time the students had been able to work together this school year. Students who had been in physical altercations with each other were encouraging each other and working together to develop a plan to dig out the longest root and keep it from breaking. This reinforced the concept that in a therapeutic garden, it is the process of gardening, not the product, that produce the desired outcome.

In Onslow County, 4-H was able to revamp the **4-H Electric programs** that were previously paused due to COVID-19 restrictions. Hands-on electric workshops and demonstrations were delivered to 80 participants. In addition, 3 4-H teen leaders co-taught some of the workshops, partially fulfilling the requirements for them to attend the 75th Annual 4-H Electric Congress at UNC-Asheville, allowing them to meet peers from across the state and explore new potential career paths in electrical work. **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.**

When the 4-H Embryology program, a popular program enjoyed annually by more than 56,000 young people, was canceled in April 2022 due to highly pathogenic avian influenza (HPAI), Extension specialists quickly teamed up to offer the **Hatch Butterflies** program as a safe alternative to 4-H Embryology. Through quick leveraging of financial support from Center for IPM, NC Cooperative Extension, NC 4-H, and Carolina Biological, over 230 butterfly kits were shipped to counties across NC. In Harnett County, 4-H adapted to the HPAI outbreak by partnering with the Harnett County Public Library to stream videos of a "virtual hatch," enabling over 100,000 online hatch-cam video views across NC. Six hundred Harnett County 2nd grade students also experienced live butterfly hatches in their classrooms. Thanks to the 'hatch butterfly' program, spring season 2022 impacted by HPAI still allowed so many youth to witness another one of Mother Nature's magic moment as a butterfly emerged from a chrysalis. **Extension and 4-H rapidly adapted to emerging challenges in order to provide safe, science-focused school enrichment programs to youth, offering them opportunities to learn about science, technology, engineering, and math (STEM) through fun, engaging activities.**

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

Citizenship is one of the three mission mandates for North Carolina 4-H. According to National 4-H Headquarters (2011), Since its inception, 4-H has placed emphasis on the importance of young people being engaged, well-informed citizens. By connecting to their communities and community leaders, youth understand their role in civic affairs and expand their role in decision-making processes. Civic Engagement is a critical life skill for youth to develop to become competent, caring, and contributing members of their communities and society. In 2022, North Carolina 4-H focused on educating youth on the importance of voting. 4-H partnered with Durham County Cooperative Extension to expand their Kids Voting Durham program

into a statewide **Kids Voting NC** program to create lifelong voting habits in children, increase family communication about citizenship, and encourage greater adult voter turnout. The program provides education as well as voting experiences. Youth who participate and vote through this program have a chance to cast their ballots, which are modeled after an adult ballot, and see the youth election results from their county on election night.

North Carolina 4-H offered this opportunity free of charge to any county that chose to participate. All supplies, including training materials, incentives, and voting supplies, were provided. Counties that decided to participate were asked to attend training sessions and provide evaluation data after the program. This program was marketed as a high-quality civic engagement experience and an opportunity to develop or enhance community partnership and support. Kids Voting NC offered 4-H programs the chance to participate at three levels. The basic level included having youth vote through an online platform. The service activity level included having the program delivered as an in-person service activity. The partnership level consisted of working with county partners to provide the program in as many locations and formats as possible. The 2022 program provided the basis for increasing the reach of participating counties in the 2023 municipal elections.

In this statewide program's inaugural year, 18 NC County 4-H programs participated, over 1,000 youth cast a ballot through the program, and 88% of youth participants reported that they would vote when they were able. At a local level, 171 youth in *Caldwell County*, cast Kids Voting ballots for federal, state and local races. This included the students of one civics teacher at West Caldwell High School, which partnered with 4-H to provide Kids Voting NC as a school-enrichment program. Kids Voting in *Cabarrus County* offered the basic level of participation which included 102 youth voting through an online platform, an in-person opportunity, or participating during an afterschool 4-H club meeting. *Rowan County* 4-H delivered the program as an in-person service activity at the Extension office. This building is a polling site, so some youths voted because they came to vote at our building precinct with their family. In contrast, other youth voters intentionally came to our site to vote due to our marketing strategies. A total of 37 votes were cast. Evaluation results collected through an online self-evaluation showed that 72 youth in *Forsyth County* cast a ballot in the inaugural year of this program. When asked how many of those who participated planned to vote when they turned 18, 88% of youth participants responded that they would vote when they were able. The 4-H Youth Development Agent and County Extension Director in *Montgomery County* presented the program to local 4th and 5th grade students within Montgomery County. The program was split into an education session for students, and then a voting day session. During the educational sessions, students were taught how to make informed decisions before voting. In Montgomery County alone, Kids Voting NC was able reach over 100 students within two of our local elementary schools. Teachers reported that this program assisted with the NC State Standards addressed in 4th and 5th grades within their curriculum. In the future, Cooperative Extension in Montgomery County plans to work with our local Board of Elections to expand this program through 4-H to reach more youth on and around Election Day, with the hopes of encouraging more families to bring their youth to vote. In partnership with the *Lee County* Board of Elections and volunteer "poll workers" representing 4-H Clubs, Community clubs, and Homeschools, Lee County sponsored a voting booth during one week of the one-stop voting center. 36 young people voted during that week. Nine young people and four adults volunteered. Adult voters commented multiple times each night about how important our work was. *Richmond Kids Voting NC* 4-H was carried out with Board of Elections during early voting and implemented in kindergarten, 5th, 8th, 10th, and 11th grade classrooms. Lessons with little kids included what a citizen is and having the right to vote. Lessons for older youth included specific information on how to register, rights and responsibilities, candidate profiles, and duties of each elected office. When asked how many of those who participated planned to vote when they turned 18, 88% of youth participants responded that they would vote when they were able. 94% of teen participants had conversations with their family members about the election. Twelve youths participated and voted in *Camden County's Kids Voting*. Several parents and community leaders who attended early voting and witnessed our voting booth gave positive feedback about the program. One middle school teacher said that she would like to be involved next time we do Kids Voting in Camden County. As summed up by one youth participating in the program, "I was glad to participate in this program, as I felt important to have my voice heard even though I am not old enough to vote in the real election." **Kids Voting NC provides an opportunity for youth in North Carolina to engage in most basic act of citizenship by experiencing the electoral process and developing lifelong voting habits. Through programs like Kids Voting NC, Extension is empowering youth to create positive change for their communities and determining a better future 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 2022 to facilitate the use and transfer of new research-based knowledge:

- #PasstheMicCamp - Tailoring Curriculum to YOUR Community

- 4-H Broiler Project - From Egg to Chicken
- 4-H Curriculum Training 4-H Concept Mapping
- 4-H Curriculum Training Clover Quest: Cultivating Cloverbuds
- 4-H Curriculum Training Cooking Up Confidence: Science with Your Snacks
- 4-H Curriculum Training Embryology
- 4-H Curriculum Training Magic of Electricity
- 4-H Curriculum Training Mooving-Milk from Farm to Fridge
- 4-H Curriculum Training Power of Wind
- 4-H Curriculum Training Residential Camping
- 4-H Curriculum Training The Wonderful World of Bees
- 4-H Curriculum Training Winged Wonders
- 4-H Pathways to the Pack
- 4-H SPARK New Youth Development Professionals
- 4-H Volunteer Management 101
- 4H Dairy Opportunities
- Children and Youth Gardening Workshop
- Deer & Turkey & Oaks, Oh My! Youth Programs from Ext Forestry
- Digging into Farm to School
- Eco Tower: A teaching tool to engage youth with the environment

- EFNEP Teen Cuisine Training
- Engaging Youth & Families in Elections & Beyond
- Ignite The Spark! Rekindling your Volunteer Program
- It's More than a Curriculum: Learn Juntos 4-H and Best Practices
- Kids Voting Implementation Basics
- Kids Voting Listening and Learning Session
- Kids Voting Overview
- Leopold Education Project (LEP) - Educators Training
- Put A Ring On It: Engaging the NEXT Generation of Volunteers
- Supporting Latina/o/x Youth & Families
- The 4-H Thriving Model: Intentional Program Design
- Trauma-Informed Practices in 4-H Youth Development
- Using GIS to Engage Youth for Community Impact
- Working with Military Youth and Families
- Youth Stepping Fourward (a Pilot Program)
- Youth Storytelling for Social Change: Tools for Effective Delivery

The following **Factsheets and Peer Reviewed Extension Publications** were developed by Extension Specialists for dissemination of research-based information to Extension agents, growers, and other stakeholders.

Calf Care Guide for Youth (AG 918)

"Se hacen puentes al andar": A Resource for Parents & Caregivers of Latino LGBTQ+ Youth (FCS 543)

"Se hacen puentes al andar": Un Recurso para los Padres y Tutores de Jóvenes LGBTQ+ (FCS 543S)

Career Exploration in Elementary School

Career Exploration for Teens

Career Exploration by Children and Teens -- An Overview

Extension specialists contributed to solving regional and national issues through **multi-state collaborative Extension efforts**. Some multi-state programs NC State Extension participated in include:

- Volunteer Conference of Southern States, a regional 4-H volunteer-led training. The conference features a hybrid delivery of more than 60 learning experiences over the four-day experience.

- Southern 4-H Volunteer Specialists Collaborative Team. Plan, program, and address volunteer needs in the Southern Region.

- 4-H Virtual "Ignite The Spark" Agent Training – Collaborated with Volunteer Specialists from the Southern Region to create, plan and implement a four-part training series aimed at helping 4-H Agents across the Southern Region reengage with and reenergize their local volunteer program.

- 4-H Military Partners Conference Planning. Multi-state team who planned and conducted the virtual 4-H Military Partners Conference.

- 4-H Military Working Group. Multi-state team working with the Department of Defense, Military Service partners, USDA, and the overall 4-H Military Partnership.

- 4-H 101: Fundamentals of 4-H Programming. Multi-state team developing an introductory online course for military-connected staff and volunteers delivering 4-H programming. The project includes staff from NCSU, Kansas State University, Colorado State University, University of Illinois, Purdue University, and Cornell University

- National 4-H's Access, Equity, and Belonging Committee for LGBTQ+ youth. Plan, develop, and implement resources for fostering more affirming spaces for LGBTQ+ youth within 4-H.

- STEMsatoinal Ag: The Virtual Farm collaboration too develop both formal and non-formal agricultural educational content for K-14 students that is appropriate for traditional school settings, as well as accommodate distance, in-person, and homeschooled children in 11 southeastern states.

- Southern Regional 4-H Horse Championships Committee Member

- Eastern National 4-H Horse Round-Up Committee Member

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 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. 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. 188,245 youth in North Carolina participated in one or more 4-H youth development programs during 2022. 4-H clubs had 19,585 members. 1,149 youth participated in overnight camping programs, 137,415 youth participated in school enrichment programs, and 46,788 youth participated in special interest programs.

delete

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

x

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.

x

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

x

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

x

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.

x

Closing Out (end date 06/11/2024)

Designing Healthy Lifestyle for Underserved Communities: Qualitative Computational Approach

Project Director
Terrence Thomas
Organization
North Carolina Agricultural and Technical State University
Accession Number
1023406

Designing Healthy Lifestyles for Under Served Communities: Qualitative Computational Approach

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

The purpose of the project is to develop a deep understanding of quality-of-life issues based on the lived experience of under-served communities. The focus is to go beyond the summary data of surveys and listening sessions to capture in rich detail a vivid picture of the life experience of community members as told from their perspective. The qualitative data produced will facilitate identifying themes that will prove useful in building personas. Personas will allow policy makers and other stakeholders to model and anticipate the reaction of communities to changes in their environment, which will make for more effective policymaking.

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.

Researchers will employ In-depth ethnographic interviews in High Point, Eastern and Southern Greensboroę covering six quality of life dimensions, and rapid thematic analysis of the data supplemented with description of the community value chain and community's response to their environment to build categories and subcategories of community members who represent the key demographics and psychographics features of community members, that is, personas. Personas represent the key attributes of community members. Researchers will use personas to convey information about community members that researchers, program developers and designers will use to design policy and programs. Personas represent the range of likely individual reaction to evolving environment. Policy makers, researchers and other stakeholders can use each persona's attribute to develop different scenarios based on personas anticipated reaction to the environment, that is, what they want and are trying to achieve, how they approach their daily activities in the current situation, the adjustments, and tradeoffs they make, their likely response to various changes in the problem situation.

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

There is the recognition among participants that good nutrition is an important aspect of achieving and maintaining a desirable level of physical activity. During the indepth interviews, members of the target audience recognize, upon refection, that motivation to adjust eating habits to improve nutritional status is low because the impact of good nutrition is not immediately obvious--humans are not good at responding to slow changing phenomenon. Many inteviewees discovered that there is more to a community than a place whee people live and work. They come to realize that community has a value chain (a system of community assests that work in concert to provide valuable service) and that they have a role in shaping this value chain. Thinking about the community in terms of its value chain bring to their attention gaps in the value chain.

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

Two different article were shared with the public, which discussed university community engagement to promote community prosperity and the use of values in intervention programs to promote healthy eating habits. Additionally, the wider public will understand the interplay among the factors that contribute to quality of life. The application of personas to summarize and capture the key demographics and psychographic features of the community, and the insights they enable make it possible for multiple stakeholders to design effective and dynamic programs rooted in the lived experience of community members.

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 team developed skills in the:

Application of multiple criteria analysis in decision making. For example, the application of Analytic Hierarchy Process (AHP) multi criteria analysis to determine the relative importance of spiritual well-being, food security and physical well-being and social connectedness QOL status from the perspective of participants and evaluating the best combination of organizations for meeting their QOL aspirations.

Application of ethnographic techniques in collecting and analyzing qualitative data, for example, development of IDI protocols, journey mapping and rapid thematic analysis.

Challenges in project implementation. Difficulty recruiting participants because of:

Fear of doing face to face interviews because of COVID-19

Fear of losing public assistance/benefits because of participation in the IDIs but would not participate without the incentive. We have done some interviews via zoom, but this approach is not a robust in providing the detailed information and interaction we seek.

Dissemination activities include the publication of articles and the explanation of project results to participants and community leaders.

Thomas, T& Thompson, A. (2022). Engagement Opportunities and Challenges of Transdisciplinary Practice: The 1890 Land-Grant Perspective. Journal of Community Engagement and Scholarship, Volume: 14 Issue: 3

DOI: 10.54656/jces.v14i3.472. Available at https://jces.ua.edu/articles/10.54656/jces.v14i3.472

Terrence, T., Gunden, C., Legesse, B. (2023, In press.). Leveraging Food-related values for impact in Community Nutrition Education Programs (Interventions). Foods

Family and Consumer Sciences

Project Director

Lauren Hargrave

Organization

North Carolina Agricultural and Technical State University

Accession Number

7001842

Annual Result: Real Money Real World

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

High school students are graduating with little or no knowledge or skills in personal finances and economics, resulting in high levels of consumer debt, such as credit card debt, bankruptcies, and student loan debt, among adults. In 2018, 28.7% of North Carolina borrowers were 75% over their credit card limit. Further reflecting recent increases in educational borrowing, for each level of education, the likelihood of borrowing is highest among those ages 18 to 29 (Federal Reserve Bank, 2017). The results show that the repayment status of student loans is highly correlated with the respondents' family background and the type of institution that they attended. In particular, individuals who did not complete their degrees or attended a for-profit institution are disproportionately likely to fall behind on their student loan payments (Saving for College, 2020). Thus, consumers are hit with higher fees on debt; the debt is sent to collection agencies resulting in lower credit scores and higher bankruptcy rates. The North Carolina bankruptcy rate for high school graduates (or higher) is 87.8%, close to the national average of 88% (U.S. Census Bureau, 2022).

Teaching youth about financial management is becoming increasingly important because this generation faces higher levels of debt than their parents. Unfortunately, many in this age group have yet to receive guidance on financial matters, especially individuals from low-income families. The Organization for Economic Co-Operation and Development (2015) conducted a study that showed of the 15-year-olds surveyed in the United States, 18% did not learn financial skills that are often applied to everyday situations, such as building a simple budget, comparison shopping, and understanding an invoice. According to the same study, there is a clear gap in financial literacy scores based on the percentage of students in a given school who receive free and reduced-price lunches. Those who receive free and reduced-price lunches tend to have lower financial literacy scores.

The CEO of the National Financial Educators Council states, "Many financial problems people face today started when they were young and making their first few financial decisions. Taking on too much debt, not investing early, and failing to plan can take decades to recover from and puts their long-term financial security at risk." Lower education levels are associated with lower earning potential. According to the U.S. Census, only 15% of Montgomery County residents have a bachelor's degree or higher. Sixteen percent of Montgomery County residents are classified as living in poverty, compared to the statewide average of 7%. As high school seniors prepare to become independent and live independently, they must learn how to budget their money, make wise financial decisions, and learn to differentiate between needs and wants when prioritizing expenditures.

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.

Real Money. Real World (RMRW) is a financial literacy program for youth ages 12-18. The program provides an interactive spending simulation that allows youth to make lifestyle and budget choices similar to those that adults make. The program includes a curriculum classroom that helps prepare the students for the simulation. In 2022, a Zoom training was conducted

by the N.C. A&T family resource management associate on RMRW for 58 North Carolina agents. The training was designed to introduce the program to the agents so they would be able to utilize it in their counties. The training covered how to conduct the simulation and the kit, which included materials and the curriculum.

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

In 2022, 525 students participated in the Real Money Real World program, initiated by two N.C. A&T agents, for a total of nine hours of instruction across four sessions.

With the help of 18 community volunteers who staffed 11 booths in Alexander County, 120 8th-grade students from West Alexander participated in the RMRW simulation. Students were assigned a career and children. Each student visited the various booths and made spending choices based on their family situation, hoping they would have enough money to make ends meet at the end of the month. The program included four classroom lessons to prepare students to assume the role of a 27-year-old adult who is the primary income provider for a family. Students learned to subtract savings, taxes, and health insurance premiums from their monthly income. The amount leftover is what they spent during the simulation activity. Students spent their money at the various booths on items typically found in a monthly budget, including housing, utilities, groceries, insurance, childcare, and transportation.

Over 70**%** of the students who attended the simulation agreed that it gave them a better idea of what is involved in earning, spending, and managing money and that the program will help them in the future. Over 80**%** learned the importance of a spending and saving plan, the cost of maintaining a household, and the cost of caring for a child. Through Real Money, Real World, 77**%** of the students plan to get more training or education after high school, 80**%** plan to start a monthly budget, and 68**%** plan to open a savings account. When asked about what surprised them the most, the majority of the students replied cost of living and the cost of childcare. One student shared, "I learned that bills have to be paid, and having children should come later in life because I saw other people have no money while I was still left with $1,000+ and no children." The program helped students have a better understanding of taxes and debt.

One student stated, "What I learned that was most surprising was how quickly you can go into debt and not be able to get out of it as easily as you got into it."

The family and consumer sciences agent in Montgomery County partnered with Montgomery County Early College to implement the RMRW spending simulation. County staff collaborated to recruit 28 community volunteers to serve in various booths. Two hundred thirty-three high school 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 (transportation, food, childcare, housing, insurance, etc.).

The successful and "eye-opening" experience taught seniors how important it is to save money, achieve higher education, and wait until they are financially ready before having children. A total of 91**%** of participants increased their knowledge about the costs of caring for a child, 85**%** increased their understanding of the costs of maintaining a household, 89**%** increased their knowledge regarding the importance of having a savings and spending plan, and 92**%** increased their understanding of deductions and withholdings. After the simulation, students reflected on their experiences and what they learned by completing a self-assessment. The students thoroughly enjoyed their experience but were shocked at how hard it was to meet a monthly budget. Many had a newfound respect for their parents and their daily lives. In a follow-up conversation with the parent of one student, the mother reported getting a phone call in the middle of the event from her daughter to say thank you for all she does as a parent. Comments from other parents indicate that the event sparked essential conversations and opened communication about budgeting. At the end of the experience, student comments included, "Kids are expensive," "I need to stay in school and graduate in order to get a better job later," "I was thinking of not going to college, but I sure am going now!", and "Life is a whole lot harder than I thought." Students also reported learning the value of paying for things they need before budgeting for the things they just wanted to have and the importance of saving - "I'm going to start saving - like TODAY!"

On another occasion, the family and consumer sciences agent in Montgomery County and their County Extension Director partnered with Communities in Schools of North Carolina to implement the RMRW spending simulation at the county's central high school. Thirty-three community volunteers served in various booths. One hundred seventy-two high school seniors participated in the event and were assigned a specific career, salary, and family size. Participants had to visit 14 booths and make spending decisions related to monthly expenses (transportation, food, childcare, housing, insurance, etc.). An additional 446 Facebook contacts were made related to this program.

Self-reported evaluation data shows that students increased understanding in all major areas of the program: the costs to care for a child; maintaining a household; the importance of having a spending and savings plan; the understanding that regular savings really add up; and that the level and quality of a person's education dramatically affects the kind of job they will get and their earning potential. The most significant knowledge improvements were seen in understanding the costs of caring for a child, the costs of maintaining a household, the number of deductions taken for taxes and other withholdings, and the importance of having a spending and savings plan. 59% of students said that following this program, they are "very likely" to consider how their spending impacts other opportunities and choices. 67% of students are "very likely" to get more training or education after high school, and 63% said they were very likely to have a money plan that includes needs and wants. Overall, 39 students were surprised to learn how much things cost in the real world, 27 stated that kids are expensive, and seven indicated that getting a good job and education is essential. Nine students said they were surprised at how hard life actually is. One student noted, "During this program, I realized how easy money is wasted very fast if you don't have a plan and stick with it." When asked what they plan to change in their life as a result of the program, 42 students wrote they would begin saving more money no (i.e., not having so many, waiting for the right time, etc.). Eighteen stated they would place more value on the type of job they get. One student shared, "This showed me that I need to change my addiction to take-out foods!ë This is just one example of how students are already rethinking their spending decisions.

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

Parents and volunteers benefited from students completing the lessons and the stimulation. Volunteers have participated more than once and offered to join in the future. Many volunteers are small business owners, retirees who have owned their businesses, and community leaders who share their experiences with others in the community. Volunteers learn more about Cooperative Extension programs. Cooperative Extension offices can build a volunteer pool. Students share their experiences with their parents, and some have contacted the agents with expressions of gratitude. Students apply what they learn to understanding what their parents deal with in caring for them and their siblings. Students also share their experiences with siblings, family members, and friends, at minimum, providing insight into the importance of saving and budgeting.

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.

Today's young adults often must deal with a variety of financial challenges, including credit card debt and debt from student loans. As consumer debt soars and educational borrowing increases, it is important to teach high school youth about financial management. Real Money. Real World (RMRW) is a financial literacy program for youth ages 12-18. The program provides an interactive spending simulation that allows youth to make lifestyle and budget choices similar to those that adults make. In 2022, 525 students participated in the Real Money Real World program, initiated by two N.C. A&T agents, for a total of nine hours of instruction across four sessions. The simulations showed the students how hard it can be to manage a monthly budget, the importance of savings, and the importance of staying in school to get a better paying job. The program also helped participating youth understand what their parents deal with in raising children and maintaining a budget.

Using a Consumption-Oriented Supply Chain Analysis to Increase Consumer Access to Local Food

Project Director
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Accession Number
1016955

Annual Result:Using a Consumption-Oriented Supply Chain Analysis to Increase Consumer Access to Local Food

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

Food insecurity and diet-related diseases are major issues for North Carolina. According to Feeding America, there are currently 1,245,879 people (or 1 in 8) facing hunger in North Carolina, and according to the USDA, just over 10% of U.S. households (13.5 million households, 33.8 million people) were food insecure at some point during 2021. Food insecurity is linked to negative health outcomes in children and adults (Healthy People 2030). At the same time, markets for local food are an important resiliency strategy, especially for small to mid-sized farmers, with economic and social benefits (FAO 2020).

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.

My major activities include three programming efforts with NC Extension agents, which have an evaluative component that serves as research about successful models of connecting consumers with sources of local food, and helping them learn how to prepare healthy meals. These include, 1) the NC Extension Master Food Volunteer (EMFV) Program, 2) Donation Stations, and 3) Farm to Early Care and Education (Farm to ECE).

1. NC EMFV Program: The Extension Master Food Volunteer (EMFV) Program was designed to support FCS agents in the delivery of food and nutrition programs by providing a formalized training and volunteer management system. By working with trained volunteers, FCS agents can expand the number of programs offered, thus increasing their community impacts through programs that teach healthy eating and cooking skills. In 2021, eleven continuing education sessions were held to train volunteers on new and trending topics, including: COVID-19 & Extension Food Programming, Understanding the Racial Wealth Gap, Local Food Directories, Sharing Stories: VA & NC Master Food Volunteers, Farm to Early Care & Education, Home Food Preservation, Diverse NC Crops, Cooking with Seafood, Food Safety for the Holidays, Working with Food Pantries, Holiday Cultural Food Traditions. An agent training was not held due to Covid, but the total number of agents in the program was 44. One agent held a virtual volunteer training with 5 new volunteers, bringing the total to 108 volunteers. These volunteers contributed 1,233 hours valued at $36,928.

In 2022, seven continuing education sessions were held to train volunteers on new and trending topics including: Farm to Pantry, Cooking Smart with Fresh Herbs, Hurricane Preparedness, Grilling 101, Pressure Cookers, Farm to School, and Donation Stations. Sessions averaged 40 volunteer and agent attendees. Ten new agents were trained in the program giving us a total of 44 trained FCS agents (high turnover in FCS agents kept our totals the same as 2021). Six agents held volunteer trainings in 2022, training 26 new volunteers, and bringing us to a total of 134 active volunteers. Volunteers contributed 1,922 service hours valued at $57,564. All of these numbers are an increase from 2021 as we continue to rebuild following the pandemic and return to in-person programming and volunteer opportunities. Volunteers worked with their agents to deliver a variety of community-based programs, including Color Me Healthy, Med Instead of Meds, SNAP-Ed, food preservation workshops, and cooking demonstrations and taste tests at community sites.

2. Donation Stations: Donation Stations seek to improve access to fresh, locally-grown food while supporting the farmers who grow it. They are designed to combat local food insecurity while raising awareness that a healthy local food system must include every member of the community. Using a simple farmers market-based approach, volunteers collect food and monetary donations from farmers market shoppers, buy directly from farmers at the farmers market, and donate the resulting food to a local hunger relief agency.

In 2022, five counties launched the Donation Station program and two counties continued the program from 2021. Agents and volunteers in each county were trained on how to manage a Donation Station, including collecting donations from market customers and educating them about food insecurity and Extension programs. Across the seven counties, Donation Stations were implemented on 68 market days with volunteers serving 445 hours.

3. Farm to ECE: Farm to Early Care and Education (ECE) enhances the health and education of young children ages 0-5 through the development of experiential learning practices and policies that connect children and their families to local food and farms. Farm to ECE includes all types of child care environments that incorporate local foods through meals and snacks, taste tests, lessons, farmer visits, cooking, growing food, and/or community and parent involvement. Since 2016, the Center for Environmental Farming Systems (CEFS)' Farm to ECE Initiative has partnered with county-based Partnerships for Children to convene Farm to ECE Collaboratives that provide technical assistance to child care centers to purchase local food and conduct experiential learning with local food. Original funding came from the Kellogg Foundation, and the initiative now operates with a combination of funding from the USDA, CDC, and PNC Bank. In 2022, we hosted a Farm to ECE institute with a contribution gift from PNC Bank to reconnect past Farm to ECE collaborative members. The one-day institute reached: 21 Counties; 19 ECE programs; 65 ECE providers; and 1164 children and families. In addition, through our USDA Regional Food Systems Partnership Program Grant, we have funding to develop local food purchasing models in four counties: Wilkes, Lee, Moore, Wayne. The project goals are to: Improve farmer profitability by developing the Farm to ECE market; Increase access to healthy, local food at ECE sites, while creating a culture of health and wellness that extends beyond children to families, child care staff, and the wider community; and, Promote community collaboration and skill sharing to accelerate and sustain progress across communities. In Year 1, we reached 2,163 project stakeholders, including approximately $20,000 sales of local food across four counties (almost 4,000% increase), reaching 29 participating child care centers, 10 households, and also serving 500 seniors who participate in Meals on Wheels. We also offered Whole center trainings for all centers in our Farm to ECE Community of Practice, held in each county, with the following attendance from the child care community: Wayne- 100; Lee- 45; Moore- 30; and, Wilkes- 54.

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

In 2021, EMFV volunteers reached 7,775 community members, and in 2022 they reached 11,773 community members.Through the EMFV program, trained volunteers engage with community members to educate them about healthy eating and cooking and local food systems. Research has shown that by cooking at home, people consume fewer carbohydrates, less sugar, and less fat, which are all important factors to help prevent and address diet-related diseases (Wolfson 2015). North Carolina community members benefit from education about healthy eating and cooking in order to address these challenges, as well as community programs to increase the availability of healthy, local food, which in turn supports local farmers.

Through Donation Stations, $5,089 was collected and spent with local farmers on market days, and used to purchase 4,459 pounds of produce that was donated to local food relief agencies. These vary between counties but can include food pantries, soup kitchens, and even community college students. Community members benefitted from the donation of fresh produce to food pantries and other hunger relief programs, and farmers benefitted from additional sales. In addition to increasing the accessibility of healthy, local food, this program engages community members and farmers to educate them about food insecurity in their communities.

Through Farm to ECE programming, children at 29 child care centers were provided fresh, healthy, local food in meals and snacks. They also learned about growing and preparing food, which will help to establish a lifelong understanding of and appreciation for local food and healthy eating. Collectively, centers purchased $20,000 worth of local food, helping to grow this market for local farmers.

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

Overall, research indicates that local food systems lead to positive economic impacts for farmers and their communities (Bauman, McFadden, & Jablonski, 2018; Hardesty & Christensen, 2016; Hughes & Boys, 2015). On the consumer side, while research does not support the idea that local food *causes* positive health outcomes (Deller, Canto, & Brown, 2017), there is evidence that involvement in local food systems increases fruit and vegetable intake increases (Alaimo, Packnett, Miles, & Kruger, 2008; Litt et al., 2011). Therefore these three projects, EMFV, Donation Stations, and Farm to ECE, contribute to broader benefits to the public by supporting local farmers while increasing consumer access to healthy, local food. In addition, evaluation of these projects, especially with Farm to ECE, results in a set of lessons learned that can help disseminate this model to other 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.

I have included some data from 2021, as I was unable to submit a report last year due to health issues. In addition to these activities, I have also published the following articles in 2021-2022 to further disseminate results to communities of interest:

Bloom, D., Boys, K., Shisler, R. C., Dunning, R., Hundley, C., & Yates, D. (2022). Exploring Models of Local Food Procurement in Farm to Early Care and Education Programs. *Journal of Human Sciences and Extension, 10*(1), 3. https://scholarsjunction.msstate.edu/jhse/vol10/iss1/3

Bloom, J.D, Yao, J., & Edwards, H. (2021). Lessons Learned from the Development of the North Carolina Extension Master Food Volunteer Program. *The Journal of Extension, 59*(3), Article 2. https://doi.org/10.34068/joe.59.03.02

Ammons, S., Blacklin, S., **Bloom, D**., Brown, S., Cappellazzi, M., Creamer, N., Cruz, A., Hynson, J., Knight, G., Lauffer, L., Liang, K., Menius, L., Piner, A., Smallwood, A., Stout, R., Stover, C., Thraves, T., & Ukah, B. (2021). A collaborative approach to COVID-19 response: The Center for Environmental Farming Systems community-based food system initiatives. *Journal of Agriculture, Food Systems, and Community Development*, *10*(2), 297–302. https://doi.org/10.5304/jafscd.2021.102.004

Hardison-Moody, A., Bowen, S., Bocarro, J., Schulman, M., Kuhlberg, J., **Bloom, J. D.,** Edwards, M., & Haynes-Maslow, L. (2021). 'There's not a magic wand':How rural community health leaders perceive issues related to access to healthy foods and physical activity across the ecological spectrum. *The Journal of Rural and Community Development*, 16(2), 23–42

In the next reporting period, I plan to continue my work with the EMFV program, Donation Stations, and Farm to ECE. In addition, I am currently on a team that is conducting a regional food system assessment in Southeastern NC, and I will have results from that project to share as well.

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.

DEVELOPED AND DEPLOYED DATA-DRIVEN APPROACHES TO STRENGTHENING LOCAL FOOD SYSTEMS: According to Feeding America, 1 in 8 people in NC face food insecurity, which is linked to negative health outcomes in adults and children. In addition to benefitting the public by increasing access to affordable, healthy food, local food systems are an important economic resilience strategy, particularly for small to mid-sized farmers. To strengthen local food systems, NC State researchers work closely with Extension, delivering data-driven models, programs, and formalized training that helps connect consumers to these local food sources. In 2022, NC State research assisted Extension in training volunteers to provide 1,922 service hours valued at $57,564. In addition, 5 counties launched the Donation Station program, and 2 counties continued the program from 2021, providing healthy local food and nutrition education to local food-insecure families. These collaborative efforts have also resulted in local food education and assistance outreach to 1,164 children and families across 21 counties. To expand on these successes, researchers are currently developing local food purchasing models in 4 counties to improve farmer profitability, increase access to healthy, local food, create a culture of health and wellness, and promote community collaboration and skill sharing.

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

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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.

x

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

x

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

x

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.

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Insect-Specific Target Systems for the Development of Novel Tools for Cockroach Control

Project Director
Coby Schal
Organization
North Carolina State University
Accession Number
1013685

Final Result: Insect-Specific Target Systems for the Development of Novel Tools for Cockroach Control

Final Result

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

Bed bugs are obligate blood-feeding pests that live in close proximity to humans. Since their global resurgence in the early 2000s, bed bugs have become one of the most challenging insects to control indoors. Bed bugs have also been shown to adversely a?ect human health, causing allergic reactions to their bites, psychological distress, and contamination of the indoor environment with histamine and various microbes. Bed bugs are now emerging as significant ectoparasites of poultry farms. Likewise, cockroaches are major pests in homes and other human-built structures. Infestations produce potent allergens that contribute to the high prevalence of asthma in infested communities. Cockroaches also harbor and transport pathogenic microorganisms in their gut and feces, as well as mechanically transport pathogens on their bodies.

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.

Bed bugs:

We used different techniques to expose bed bugs and German cockroaches to *Beauveria bassiana*, a fungal pathogen that only infects insects, to test their susceptibility to infection. The tests with bed bugs revealed that they were highly susceptible to fungal infections, no matter how we exposed them to the pathogen. German cockroaches were only infected by fungi through certain routes of exposure. Fungal pathogens have the potential to control bed bugs but will require additional research and innovative technologies to be effective against cockroaches.

Following a blood meal, bed bugs deposit fecal material indoors. The feces contain a variety of compounds, including histamine, which serves as a component of their aggregation pheromone. Histamine is a pivotal mammalian immune modulator, and recently we showed that it is present in high concentrations in household dust from homes infested with bed bugs. We analyzed bed bug fecal material from different life stages and populations, along with fecal material collected at different post-feeding times and from bed bugs fed on different diets. Our analysis showed significant variation in histamine excretion among life stages, with mated females excreting the most histamine and first instar nymphs excreting the least histamine. There was no difference in histamine excretion among laboratory and recently home-collected bed bug populations. Further, we found histamine excretion continued for at least 14 d post-feeding, with the highest amount of histamine excreted 3–4 d after a bloodmeal. Overall, this work demonstrates that bed bugs excrete histamine across all feeding life stages, populations, and at various times after feeding, and that histamine excretion is directly related to blood feeding. These results will be used to better understand the health risks associated with histamine excretion and potential mitigation strategies of environmental histamine.

Bed bugs are also ectoparasites of chickens in poultry farms, where frequent biting and blood-feeding are expected to cause stress, infections and even anemia in birds. Bed bug control options are limited. We proposed that veterinary drugs, which are commonly used to control ectoparasites in animals, could be used against bed bugs. Using an artificial feeding system, we showed that both ivermectin and fluralaner caused high mortality in insecticide-susceptible bed bugs, and fluralaner was effective on pyrethroid- and fipronil-resistant bed bugs. Ivermectin was ineffective in chickens, but bed bugs that fed on chickens which had ingested fluralaner suffered high mortality when feeding on these chickens for up to 28 days post treatment. These findings suggest that systemic ectoparasitic drugs have great potential for practical use to control bed bug infestations in poultry farms. These findings also demonstrate the efficacy of fluralaner (and potentially other isoxazolines) as a potent new active ingredient for bed bug control.

Selection on bed bugs with pyrethroid insecticides has intensified over the last 2 decades. We examined temporal changes in the frequencies of three kdr-associated mutations in C. lectularius populations collected across the USA from two time periods, sampled approximately a decade apart. We found a significant increase in the frequencies of kdr-associated mutations over this period and the absence of the insecticide-susceptible genotype in recent collections. Furthermore, we observed a significant transition toward infestations possessing multiple kdr-associated mutations. These findings suggest that the persistent use of pyrethroid insecticides over the past decade continues to impose strong selection pressure on C. lectularius populations, driving the proliferation of kdr-associated mutations. They demonstrate that, if unabated, strong anthropogenic selection can drive the rapid evolution of adaptive traits.

Long-lasting pyrethroid-treated nets have historically been, and remain, one of the most commonly used vector control tools in the campaign against malaria. The emergence of pyrethroid-resistant bed bugs in malaria-endemic communities and failure to control infestations have been suggested to interfere with the effective use of bed nets. Therefore, the behavioral interactions of bed bugs with commonly used bed nets should be better understood. We found that both insecticide-susceptible bed bugs and highly resistant bed bugs were able to pass through bed nets, with minimal mortality only in the susceptible bed bugs. The overall low mortality highlighted the potential of bed nets to impose strong selection pressure for the evolution of pyrethroid resistance. For the first time to our knowledge, we have shown the potential of bed nets to select for resistant secondary pest populations and thus their potential role in stalling malaria control programs.

Cockroaches:

The phenylpyrazole insecticide fipronil has been used extensively to control German cockroach populations, exclusively in baits, yet the highest reported fipronil resistance is 38-fold. We evaluated five populations of German cockroaches to determine the status of fipronil resistance. Resistance ratios in field-collected strains ranged from 22.4 to 37.2, indicating little change in fipronil resistance over the past 20 yr. In contrast, resistance to pyrethroids continues to escalate. We assessed the roles of detoxification enzymes in fipronil resistance with four synergists previously shown to diminish metabolic resistance to various insecticides in German cockroaches—piperonyl butoxide, S,S,S-tributyl phosphorotrithioate, diethyl maleate, and triphenyl phosphate. We also found that all field-collected strains are homozygous for a mutation that substitutes serine for an alanine (A302S) in Rdl, and confers low resistance to fipronil. Understanding why cockroaches rapidly evolve high levels of resistance to some insecticides and not others, despite intensive selection pressure, will contribute to more efficacious pest management.

In the German cockroach, a gustatory polymorphism, 'glucose-aversion (GA)', supports greater survivorship under selection with glucose-containing insecticide baits and promotes the evolution of behavioral resistance. Yet, sugars are prominent components of the male's nuptial gift and play an essential role in courtship. Behavioral and chemical analyses revealed that the saliva of GA females rapidly degrades nuptial gift sugars into glucose, and the inversion of a tasty nuptial gift to an aversive stimulus often causes GA females to reject courting males. Thus, the rapid emergence of an adaptive change in the gustatory system supports foraging, but it interferes with courtship. The trade-off between natural and sexual selection under human-imposed selection can lead to directional selection on courtship behavior that favors the GA genotype.

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

Our target audiences consist of several distinct groups:

Scientists:

Our findings have motivated a wide range of scientists to follow-up on our discoveries. These include entomologists, chemical ecologists, toxicologists, ecologists and behavioral biologists.

Graduate students and postdoctoral trainees:

2 postdoctoral trainees, 2 professional PhD-level scientists, 2 visiting professors, 5 graduate students and 2 undergraduates were trained.

Industry:

Companies that innovate and produce pest management products benefit from our research findings. They can use reagents that we generate, such as chemicals and genetically characterized lineages of insects.

Regulators:

State and federal regulators need to know what works and what does not work in pest control in the public sector. Our research findings inform regulators about the benefits and hazards associated with various pest control strategies and products.

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

Pest control industry:

Our research findings guide the activity of thousands of pest control professionals throughout the U.S. and globally. We provide in-person and virtual presentations about our findings in recertification conferences and workshops.

Students:

Our published articles are routinely used in classrooms to highlight examples of rapid evolution in the human-built environment. Our behavioral analysis and videos associated with our research are used in classrooms across a broad range of ages.

The Public:

The general public faces challenges with household pests. These range from medical or health related issues (e.g., bed bug bites, cockroach allergens that trigger asthma) to food contamination, psychological distress, and decisions about pest management strategies and products. Our research provides evidence-based information that serves consumers as they navigate the confusing landscape of pest control services and 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.

The COVID-19 pandemic has been particularly challenging because much of our research activities are in low-income homes, places where the pandemic was especially severe. We re-oriented some of our research to lab-based activities, including characterizing home biocontaminants from archived samples.

In 2022 we experienced extensive delays in visa applications for visiting scientists and postdoctoral fellows, some of whom were denied their visa applications.

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.

LAID GROUNDWORK FOR MORE EFFECTIVE PEST CONTROL OF BED BUGS AND COCKROACHES: Bed bugs and cockroaches have been shown to adversely affect human health, causing allergic reactions, contamination, and psychological distress. Bed bugs are now also emerging as significant parasites affecting poultry farms. NC State researchers have discovered insights into potential new approaches to controlling these pests. They discovered that cockroaches are highly susceptible to fungal infections, they analyzed bed bug production of histamine (a substance that provokes immune system reactions) to better understand the health risks associated with histamine and support potential mitigation approaches, and they discovered particular drugs and drug classes that have great potential for controlling bed bug infestations in poultry farms. In addition, they found evidence that the use of bed nets to prevent bed bug infestation is likely ill-advised because it may contribute to the development of insecticide resistance. They also developed a deeper understanding of why cockroaches rapidly evolve high levels of resistance to some insecticides and not others, laying groundwork for more effective management of these pests. These findings benefit researchers, the pest control industry, public sector regulators, and communities coping with cockroach and bed bug infestations.

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

x

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.

x

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

x

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

x

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.

x

Community Development

Project Director

Lauren Hargrave

Organization

North Carolina Agricultural and Technical State University

Accession Number

7004285

Annual Result: Civic Engagement

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

Clear patterns indicate civic engagement levels are lowest for poorer, less educated, young, and non-white citizens. These groups are more vulnerable to being disconnected from programs and activities that could enhance their well-being. Civic engagement programming is needed to facilitate positive changes at the community level.

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 2022, Extension agents in community and rural development (CRD), 4-H, family and consumer sciences (FCS), and small farms in Edgecombe, Nash, and Caswell counties conducted programming for youth and adults that focused on improving communities through civic engagement and leadership.

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

The Edgecombe Entrepreneur Organization (EEO) was started in the 1980s by Edgecombe Extension staff to foster, develop, and expand entrepreneurship among African American residents of Edgecombe County. Through the years, EEO has needed to adapt to changing times. The group has about 20 active members who are very engaged. However, it always seeks additional members with new skill sets, best practices, and leadership potential. As a result, with the assistance of the Edgecombe County CRD agent, EEO held a leadership retreat to enhance its leaders and analyze its mission to ensure it serves Edgecombe County well. Twelve EEO members, including its president, gathered with the Extension CRD agent and an outside facilitator to participate in several organizational development activities. These activities led EEO to design new meeting procedures, adopt a new organizational mission, and prepare to focus on creating a succession plan in the upcoming year. The group also decided to begin a new membership recruitment effort to develop new entrepreneurs to serve the residents of Edgecombe County and surrounding areas.

The Nash County 4-H and CRD agents hosted a school supply drive for Nash County's limited-resource youth this fall. Residents were asked to drop off supplies at the Nash County Extension Center through a multi-faceted media campaign. Through overwhelming support from the CRD Advisory Council's communities and Nash County residents, we collected school supplies and donations to support the endeavor. Of these, major donors included:

• Nashville Willing Workers Club– provided $200 for school supplies.

• Braswell Family Farms -employees held a collection and donated a large number of school supplies.

• Stoney Creek Cowboy Church-donated school supplies and made a monetary donation for supplies.

• Joyner family- used the supply drive as their community project and donated many school supplies.

• Winwood Community and Peachtree Community - donated school supplies.

• Other community members and 4-H families brought in bags, boxes, and containers full of school supplies.

The supply drive was an enormous success, with local residents and community organizations donating over $1,500 in school supplies for limited-resource youth. The supplies were shared with our community partner, Nash Communities in Schools, which provides direct community services and support to youth in Nash County schools. This was done to ensure the supplies were provided to needy youth.

To address food insecurity in Caswell County, the small farms' Extension agent, and the FCS agent teamed up to organize a food drive as a part of N.C. A&T State University Extension's annual Small Farms Week celebration. Food items were collected from communities around the county. As a result of the 2022 food drive, the Caswell County agents collected more than 350 nonperishable food items worth more than $270. The collected items were donated to the County Outreach Ministry Food Pantry in Yanceyville.

The Harnett County CRD agent and Erwin Churches Helping Others (ECHO) partnered to address the issue of food insecurity. This partnership provided food boxes (20 lbs. per food box) to 75 limited-resource families each month and supplied four blessing boxes (500 lbs. a week) in four communities in the county. As a result, Harnett County residents can offer a Blessing Box, which provides nonperishable food (like cereal, canned soup/pasta, and granola bars) as well as hygiene items (including shampoo, soap, toothbrushes/toothpaste, and toilet paper) to people when they are needed. This initiative now includes several churches stocking the boxes as a part of their ministry. We received a $23,000 grant from Resourceful Communities to increase the capacity of our food giveaways to include fresh fruits and vegetables.

Too many families in Avery County, especially the elderly on fixed incomes, experience difficulty affording fresh produce when purchasing groceries. The Avery County food pantries continue to supply weekly food to families struggling to make ends meet. The children in the Avery County 4-H Summer program planted a garden tended it, and produced over 100 pounds of fresh food delivered to the Reaching Avery Ministries food pantry. Fresh produce was distributed to families in Avery County. The students learned gardening basics by actively tending to their garden, harvesting food, and personally delivering their produce to the food pantry. More importantly, the concepts and practice of giving and sharing with others were reinforced in this program

Using a positive, asset-based approach, the Nash County CRD agent highlighted assets and strengths to assist the county in creating a five-year plan for the Nash County Arboretum. By taking high points from the past and looking at needs for the future, Master Gardener volunteers were able to agree on a vision for the Arboretum. The three-session planning process focused on goals and strategies to fulfill the mission of the Arboretum and strategies to move toward its vision for the future. Looking at the strengths, weaknesses, opportunities, and needs of the Nash County Arboretum, the group devised an action plan for the next five years. The planning sessions confirmed a strong need for cleared pathways and signage for the Arboretum. The volunteers want the Arboretum accessible for all Nash County residents, including patrons with strollers, walkers, and wheelchairs. Using information gathered from these sessions, the Nash County horticulture agent applied for a $155,000 environmental grant to help improve pathways.

With the ongoing COVID-19 pandemic, EEO and CRD programs realized they could not successfully host the annual Dr. Martin Luther King, Jr. commemorative banquet while keeping their guests safe from COVID.. Instead, they partnered with the local chapter of a national organization, Sleep in Heavenly Peace (SHP). SHP provides children with much-needed beds to sleep in to get good rest before school. The EEO and the CRD program contacted previous banquet sponsors to raise money for the beds. EEO, SHP, and volunteers decided to build single and bunk beds for children in need. The EEO and the CRD program raised over $5,400, with donations continuing. So far, SHP, EEO, and volunteers have built 27 single beds and bunk beds for Edgecombe County children.. Children are provided with a bed, pillow, and bed linens.

The CRD agent heard from several Edgecombe County residents about difficulties obtaining N95 and NK95 masks. The Edgecombe County Health Department gave each resident one N95 mask while supplies lasted, which was not enough to meet the need. . The CRD agent began researching alternatives and learned that North Carolina had a program in which nonprofits and state agencies could apply to obtain N95 masks and other PPE to assist their communities. In January 2022, the CRD agent successfully applied to the s program to get 200 N95 masks to distribute to the community. Forty Edgecombe County residents received five N95 masks each. The high demand continued, and in February 2022, the CRD agent

successfully applied for 400 additional N95 masks. In partnership with the Edgecombe Entrepreneur Organization, 80 Edgecombe County residents received hard-to-find N95 masks for a total distribution of 600 N95 masks to 120 residents. The masks were reusable and helped the 120 residents remain COVID free.

The CRD agents in Edgecombe County, Harnett County, and Nash County collaborated to create the "Be Prepared: Disaster Preparedness" workshops. The CRD team hosted two disaster preparedness sessions for 42 participants. Participants lived in Edgecombe County, Harnett County, and Nash County. The sessions included:

- Information related to preparing for various types of natural disasters.
- Previous disasters' financial impacts on communities.
- Creating an emergency preparedness kit.
- Mitigation efforts.
- Getting electronic weather alerts.

All participants reported increased knowledge of disaster and emergency preparedness techniques and tasks. Less than 40% of participants reported not having a written emergency plan. Over 80% of participants reported they would create or revise their household emergency preparedness plan. The CRD agents were invited to present some of their information to an additional 20 participants at N.C. A&T Cooperative Extension's 2022 Grassroots Leadership Conference.

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

All the activities conducted by these agents have helped enhance their communities. When underserved youth have school supplies, they are better able to learn, contributing to a more successful future for all. When individuals are provided the resources needed to succeed, it begins to create worldwide equity.

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.

Civic engagement levels are lowest for poorer, less educated, young, and non-white citizens. These groups are more vulnerable to being disconnected from programs and activities that could enhance their well-being. In 2022, Extension agents in community and rural development (CRD), 4-H, family and consumer sciences (FCS), and small farms in Edgecombe, Nash, and Caswell counties conducted programming for youth and adults that focused on improving communities through civic engagement and leadership. Programs included revitalizing the Edgecombe Entrepreneur Organization, a group launched in the 1980s to foster, develop, and expand entrepreneurship among African American residents of Edgecombe County; coordinating a school supply drive for limited-income students in Nash County; organizing a food drive in Caswell County; and delivering food boxes to needy families in Harnett County. Other activities included planting a community garden and distributing masks to populations vulnerable to COVID-19 infections. All these activities have benefitted communities and demonstrate that individuals have the power to make change if they have the resources they need.

Annual Result: Community Garden Program

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

Community gardens are about much more than growing food. They provide safe spaces for people to learn about diverse cultures, share ideas, protect and regenerate the environment, and provide educational experiences for youth and adults alike. According to the NC Food Justice organization, “In North Carolina, people in 590,000 households do not have enough food to eat daily. North Carolina has the 10th highest food insecurity rate in the nation.” Food insecurity continues to rise in rural and urban areas, resulting in increased illness, food culture loss, and loss of knowledge about the origins of fresh food. To help alleviate food insecurity, successful community gardens empower people and introduce them to the local food systems network, such as food councils and food pantries. Many communities attempt to support those suffering from food insecurity but do not have the organizational understanding or leadership skills to maintain successful community garden programs.

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 Community Garden Program is a statewide initiative to increase gardens in food-insecure North Carolina communities. The program provides opportunities to collaborate with our diverse Extension agents and community leaders across the state to develop place-based programming that provides gardeners with the skills and resources they need to build and sustain their gardens. A strong community garden network will minimize food insecurity and maximize shared learning and leadership opportunities.

2022 was the second full year of the Community Garden Leadership Academy (CGLA) training program, and four training sessions were held in three regions of the state. The Community Garden Coordinator partnered with eight Extension agents and two community leaders to facilitate the training. The CGLA continues to build relationships among community members and Cooperative Extension agents in their counties. The CGLA is a direct pipeline to the virtual network where gardeners support each other by sharing resources and experiences. The online community garden network has 214 active members, which is 102 more members than last year. Community members from different gardens can meet, share experiences and stories, and contribute to a shared vision for their counties. Additionally, the program now has 74 newly trained mentors to support developing gardens.

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

The first training was in Rutherford and McDowell counties in the state’s western region. Thirty participants attended this training. According to the evaluations, 92**%** of the participants were able to share several community gardening best practices at the end of the training, and 100**%** shared information and resources about community gardening. All participants were from either Tier 1 or Tier 2 counties (i.e., Rutherford, McDowell, Stanly, Cleveland, and Gaston).

The second training was held in Forsyth County in the Piedmont region of the state and was facilitated by the County Community and School Garden Coordinator and a local community leader. Out of the 17 participants, eight completed the evaluation. According to the evaluations, 100**%** of the participants learned new skills in each evaluation area. Almost all participants—99**%**--came from Forsyth County, a Tier 1 county. Two of the community gardens in this training applied for the collaborative stipend, which will support them in partnering with two more gardens in the area.

The third training was in Eastern North Carolina. The Community Garden Coordinator partnered with the Agriculture and Natural Resources (ANR) Extension agent in Pitt County. Even though there was a waitlist of more than 32 gardeners, only 11 registrants came and participated on both days, representing five gardens. One participant was not affiliated with a garden. Even though the training was smaller than expected, the participation and connections made were significant. Before and after the program, program attendees were surveyed about their abilities to help local groups troubleshoot common community garden problems and locate reliable resources. On the pre-assessment, four respondents rated their abilities as "very low," while one rated them as "high." When asked the same question about their abilities after the program, 40**%** of participants believed their abilities had improved. When asked before the program about their knowledge of asset-based community development, every participant responded "low" or "very low." After the program, they all believed they had improved their knowledge. Sixty percent of participants were from Tier 1 counties and 40**%** from Tier 2 counties (i.e., Onslow, Granville, Pitt, Beaufort, and Wake).

The last training of the year was held in Guilford County in collaboration with the Guilford County Extension Center and student support services. There was a waitlist of more than 35 participants, but only 16 attended on both days. According to the evaluations, every participant gained knowledge in every topic, averaging 3.5 out of 5. Five gardens were represented, and three unaffiliated new gardeners attended. All attendees have gardens in Tier 2 counties except one whose garden is in a Tier 3 county (i.e., Guilford, Rowan, Orange, and Catawba).

Eight gardeners used space at the Aggie Community Garden on the N.C. A&T University Farm to grow vegetables for their families. The church that rented space the previous year did not renew because the gardeners are elderly and unable to commute to the garden as much as needed. In 2022 a perennial pollinator garden was designed and planted to demonstrate the importance of pollinator species for food production. A pathway was constructed that makes the community garden more accessible from the University Farm Pavilion.

The student health center's student garden on campus continues to be a great success, with 10-18 students regularly volunteering to plant, weed, water, and harvest. The students harvested 75.59 lbs. of produce, all of which went to the campus food pantry and the student volunteers. Our role in this garden is seed starting, planting with the students, and other technical support.

In 2022, 28 community gardens were awarded a $1,000 stipend to improve their gardens. This stipend program is part of the Blue Cross Blue Shield Foundation grant. Thirty-seven percent of the recipients were from Tier 1 counties, 29.6% from Tier 2 counties, and 33.3% from Tier 3 counties.

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

Successful community gardens produce more healthy food, which goes back into the community by sharing with food pantries and neighbors. With continued support and connection to the broader community garden network, the success of individual gardens will inspire local communities and build a sense of agency.

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.

McKim, A. M. (2022). Community Fresh: A guide to growing community gardens. https://online.fliphtml5.com/nbdy/pccr/#p=1

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.

Community gardens are spaces that grow healthy fresh foods and offer a safe space where people can share ideas, learn about other cultures, and play a role in creating healthy community environments. The Community Garden Program is a statewide initiative to increase gardens in food-insecure North Carolina communities. The program collaborates with Cooperative Extension, which helps it build a strong community garden network through a program called the Community Garden Leadership Academy (GCLA). The GCLA teaches best practices in establishing and maintaining a community garden and helps garden leaders connect with other community leaders to address food insecurity in their communities. Now in its second year, the GCLA offered training in the western, eastern and Piedmont regions of North Carolina in 2022. The CGLA is a direct pipeline to the virtual network where gardeners support each other by sharing resources and experiences. The online community garden network has 214 active members, which is 102 more members than last year.

4-H Youth Development

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

Annual Result: 4-H Robotics

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

The future job market will require employees to have at least a fundamental understanding of reading and writing computer code and computational thinking. Robotics is an engaging way for youth to learn the basic concepts of coding and computational thinking. Robotics brings coding and STEM (science, technology, engineering, and math) to life. Youth can

immediately see the results of their programs, debug them, and make corrections as necessary. Coding prepares students for success in high-demand careers in STEM. It is essential to provide opportunities for youth to learn coding at an early age.

The most significant drop in STEM interest among school-aged youth occurs between 3rd and 5th grade. This supports the notion that STEM exploration should be focused on this age group, even though much popular support for STEM education focuses on the upper-level grades. Research also suggests that STEM exploration outside the classroom is better received than classroom education.. Leadership development is also a primary component of the National 4-H mission to empower youth to reach their full potential by working and learning in partnership with caring adults. Youth of all ages can learn and exhibit leadership skills, and coupling these with robotics offers a fun and engaging way to learn and practice those 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 robotics training series was held in 2022 to prepare 44 4-H agents, 4-H program assistants, and volunteers to implement coding and robotics programs across NC. The training content included lessons and strategies for implementing coding and robotics with youth ages 7 to 18. Training and materials for elementary school youth included Wonder Workshop's Dash and Dot and Lego Education's WeDo 2.0, which 21 participants attended. The training and materials aimed at youth in upper elementary through high school included Lego Education's Spike Prime and Parrott Mambo drones, which 23 participants attended. Additionally, several agents planned workshops using the materials as a loan to their counties. Technical assistance for the robotics and coding program has been ongoing via email and phone.

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

In 2022, a total of 632 4-Hers participated in 4-H Robotics for a total of 44 hours of instruction across 60 sessions.

The N.C. A&T 4-H Extension agent in Guilford County partnered with the High Point Public Library Children's Department to deliver a two-day, three-hour camp focused on developing leadership skills using LEGO SPIKE Prime kits and Wonder Workshop's Dash. The group discussed the qualities of great leaders (and not-so-great leaders) and worked on skills related to teamwork and communication. Twelve Guilford County youth attended the two-day camp. Evaluation data revealed an overall increase in knowledge about communication, leadership, and technology among participants in the camp. Youth were excited to share their existing knowledge of leadership as well as learn and implement new skills. Throughout the camp, they worked in teams of two or three to solve problems and share creative ideas with their peers. When asked what they enjoyed most about the program, many shared that they enjoyed working with the robots and programming them to navigate a maze. One participant also shared that they enjoyed the interactions with other people. The Guilford County 4-H agent solidified a partnership with the Children's Department at the High Point Public Library and will discuss future programs for new and returning participants.

Guilford County 4-H hosted a one-day camp for youth ages 11-14 to explore electricity using Littlebits STEAM kits from N.C. A&T. During the camp, six youth learned about simple circuits and computational thinking while using the kits to build survival systems for a Mars basecamp, communication devices, and robotic arms. Working in teams of two encouraged effective peer-to-peer collaboration. Parents were invited to join the last ten minutes of the session to learn more about participating in the 4-H Electric Program. As a result of this program, there was an overall increase in familiarity with electricity and computational thinking--a transferable problem-solving skill youth can use in all aspects of their lives. Participants shared that they enjoyed building with the kits and making new friends. A few participants were interested in further participation in the 4-H Electric Program. This one-day camp also laid the foundation for future sessions to continue learning for past participants and increase awareness and knowledge among a new group of 4-Hers.

The 4-H agent in Guilford County partnered with five agents from other counties during the summer to host a 4-H Robotics Camp for 53 middle school youth. The camp included activities on catapults, WeDo Robotics, Spike Robotics, EV3 Robotics, and Drones. Participants built robots and programmed them to do different tasks using coding methods. Drones were introduced this year at the camp, which was very successful. The youth got to fly drones on their own and hear from an Extension agent about how drones are used in agriculture.

The camp helped youth see what opportunities were available and learn job-ready skills. Surveys showed that 56% of the participants learned problem-solving skills, 58% said they could compare and select materials based on how they would affect a design, and 69% stated they could create a cost-effective product. There were several life skills that youth were asked about, and results showed that 81% gained skills in teamwork, 77% in creativity, 71% in sharing, 69% in decision-making, and 83% in communication. All of these skills will prepare youth for a technologically demanding workforce.

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

A better-prepared future workforce impacts the broader public. Also, risky behavior is reduced when young people are engaged in hands-on programs, affecting communities' safety and prosperity.

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 4-H STEM Specialist plans to continue to provide technical assistance and professional development opportunities to 4-H staff and volunteers. With grant funds from the Children, Youth, and Families at Risk partnership with NC State, there will be focused efforts to provide advanced robotics resources to teachers in Bladen and Harnett Counties initially and then made available across the state.

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.

Coding and computational thinking will be required skills in the future job market and the 4-H Robotics program is a fun and engaging way to teach youth these skills. The act of building and programming a robot allows kids to see the results of their programs and debug and make changes as necessary. In 2022, the 4-H Robotics program reached 632 4-H members with 44 hours of instruction across 60 hours. The 4-Hers learned coding and robotics at one- and two-day camps, where they worked in teams and also learned important skills in problem-solving, leadership, teamwork and communication. Extension at A&T also provided training to 44 4-H agents, program assistants, and volunteers, who were then able to implement coding and robotics programs across North Carolina. The program provides youth with positive experiences in science, technology, engineering and math (STEM), keeps them away from risky behaviors, and helps develop the skilled workforce of the future.

Annual Result: Tinker Boxes

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

Jobs in science, technology, engineering, and math (STEM) are expected to grow at higher rates over the next few years than non-STEM jobs (Zilberman & Ice, 2021). However, many young people are not prepared for college-level math or science courses upon graduation (ACT, 2022). Helping youth find their STEM spark is essential to the success of our future workforce and the responsibility of schools, youth-serving organizations, and family members. Family members and caregivers directly impact young peoples' early interests in science through their occupations, hobbies, and encouragement (Dabney et al., 2013). Even parents who are not formally educated beyond high school can play a significant role in their children's interests in STEM.

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 STEM Specialist with Cooperative Extension at North Carolina A&T State University, developed the Tinker Box Program during the pandemic to capitalize on family engagement and increase interest in STEM among youth in North Carolina. Tinker Boxes are experiential activities and materials for families to use as a springboard to generate curiosity and interest in STEM concepts. Parents and other family members create a youth-adult partnership to complete the activities as a team. In 2022, families received engineering and science-themed Tinker Boxes to work on together in their homes. The themes for the boxes were: engineering (February, to coincide with E-Week); Earth Day (April); and summer fun (June). All

materials to complete the activities were provided, except for some recyclable household items, such as paper towel tubes and cereal boxes. Parents were asked to team up with their youth to complete the activities and to complete a survey afterward to capture their thoughts about their STEM experiences with their children.

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

The Tinker Box Evaluation (TBE) responses included 138 parents/guardians and 227 children. On average, children and parents reacted positively to the Tinker Boxes. Nearly 87% of the families reported working together on each Tinker Box project for approximately one to two hours. Seventy-six percent (76.1%) of families indicated that before this opportunity, they occasionally or frequently worked on science activities outside of school with their children and 100% said they are somewhat or extremely likely to engage in science activities in the future. The vast majority of parents (84.8%) indicated that they learned science and engineering concepts by participating in the activities, as well as 97.1% of the children. Regarding their comfort level, 90.6% felt quite or extremely comfortable completing the activities with their children, and 88.4% felt they were their child's partner. Parents reported that their children (86.2%) and themselves (92%) enjoyed working as a team. Almost all participants (99.3%) , said they would be interested in future Tinker Box activities.

When families were asked what they enjoyed most about the program, a variety of responses were received, including the following:

- *"…I also enjoyed feeling more like a partner completing the assignment instead of a teacher."*
- *"I enjoyed being able to teach my children engineering concepts in a fun way."*
- *"Working with my kids to learn new concepts and spend time together."*

Parents also discussed the utility of the materials provided. Specifically, one parent who built a wind lift with their child stated, *"Many projects like this are not sturdy enough to stay together, but this build has continued to function for several weeks now. I also like that it can be modified."* Other positive feedback indicated that the activities were fun, and parents liked that they were free. At least four families who homeschool their children enjoyed having materials to add to their curricula. This positive feedback indicates that the Tinker Box Program was successful in getting parents and their children to work together on fun and educational science activities. These activities, conducted in informal settings, can build an interest in STEM at a young age.

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

Engaging in STEM with families in an informal setting can encourage youth to some day pursue careers in STEM, alleviating the shortage of individuals in STEM fields, bringing more diversity to STEM fields, and opening up new opportunities for rewarding, high-paying jobs for North Carolina youth.

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.

As jobs in science, technology, engineering and math (STEM) dominate the workforce, it is essential to ensure that young people have experiences that prepare them for college-level math and science. The 4-H STEM Specialist with Extension at A&T developed the Tinker Box program during the pandemic to capitalize on family engagement and increase interest in STEM among youth in North Carolina. Tinker Boxes are experiential activities and materials for families to use as a springboard to generate curiosity and interest in STEM concepts. In 2022, 138 parents/guardians and 227 children participated in the program, receiving Tinker Boxes with themes of engineering, Earth Day, and summer fun. Parents and children reacted positively to the Tinker Box program and enjoyed the chance to work together as a family on hands-on STEM projects.

Annual Result: Youth Stepping Fourward

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

Typically, underserved youth do not have access to leadership development programming, which leads to a missed opportunity to view themselves as future leaders and utilize their voices. Minority and low-income children are at risk of not reaching their full potential. They are less likely to participate in leadership development and civic engagement opportunities and experiences than their counterparts.

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 Youth Stepping FOURWARD (YSF) was to create opportunities for rural and urban youth to enhance their leadership development and public decision-making skills. According to our last strategic plan (*Mission Possible*), this program helps to address two programming issues in youth and leadership development. Moreover, the initiative was piloted at a critical time during the COVID-19 pandemic when most programming opportunities were completely virtual; however, it provided an opportunity for them to fully access and participate in 4-H in meaningful ways that helped them learn and thrive with their peers.

The major program activities for 2022 included: (1) training a cohort of Extension professionals, youth leaders, and 4-H volunteers to serve as facilitators of the program; (2) providing youth participants with training sessions over nine (9) weeks where they learned leadership and decision-making skills and discussed and worked as part of a team to address a community issue of shared concern; and (3) helping youth execute a service-learning project of their choice.

We introduced the program to one urban county (Chatham), a suburban county (Catawba), and six rural counties (Haywood, Vance, Hertford, Harnett, Mitchell, and Halifax). Four counties were Tier 1 counties (Halifax, Mitchell, Vance, and Hertford). One hundred youth participated, and nearly two-thirds were considered limited-resource or non-traditional. The program steps were followed for everyone. The program specialists provided co-facilitation training for the Extension professionals and community volunteers. After the training, 4-H staff recruited youth to t the program. Once the intake process was completed, the youth participated in the training and completed a community service project.

After the program, we sought to encourage the youth participants to:

- Facilitate positive and meaningful partnerships between their peers, adult volunteers, and 4-H professionals;
- Problem-solve and collaborate with other local community members to identify local issues and develop strategies for addressing those issues; and
- Build essential life skills for them to emerge as leaders and become contributing community members.

Because the program had a positive youth development focus, we also looked at belonging, mastery, independence, and generosity.

Belonging:

With the guidance of youth leaders, 4-H staff, and adult volunteers, youth participants identified commonalities within the community, developed an action plan for their community service project, and were supported as they executed their community project. As a result, they developed critical relationships with community leaders and positive friendships within their peer group.

Mastery:

Over the project period (which covered a span of 3 to 4 months), youth demonstrated different skills, including listening to and articulating community needs with others; learning to work together as a group; developing a vision for their community; utilizing communication techniques,; setting goals related to the issues they discussed; carrying out a youth-led project; positively taking action, facilitating conversations, and presenting their ideas and work to others.

Independence:

Teens were able to see themselves as active participants within their communities. They motivated their fellow peers and led by example. They also exhibited greater confidence and optimism.

Generosity:

Because the training program was about building and training youth groups with leadership skills, they worked together as a team/group to make a difference in the community. By engaging them through an action plan process to carry out a service-learning project of their choice, they had an opportunity to value and practice service to others and contribute to the broader community.

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

Overall, the program was piloted in eight counties and engaged 100 youth. The youth successfully tackled issues they were concerned about, such as food insecurity, youth violence, and caring for the natural environment. Below is a description of some of the immediate outcomes captured at the end of the training program:

Mitchell County youth planted and tended a garden throughout the summer, raising squash, cucumbers, tomatoes, eggplant, and herbs. All vegetables harvested - approximately 110 lbs. of produce- were donated to a local food pantry.

In **Halifax County**, youth used the knowledge to better visualize their community and local food system. They decided to use GIS coding and mapping to capture different data points that were not readily available, such as demographics, local food consumption, restaurant spending, and other regional assets (fresh food growers, distributors, processors). This helped them identify the local assets and gaps in accessing healthy food choices in a five-county area. Their work in this project received 1st place in a state GIS competition. They also partnered with the local county Extension Center to complete walk audits, effectively engaging diverse community representatives in defining physical and structural aspects of the community they want to improve.

Utilizing the training they received through YSF, the youth in Hertford County reached out to about 40 peers to examine how they are affected by community issues. The youth presented the results to community leaders and the town mayor's Community Invention Task Force. Some of the top issues youth identified included mental health, violence, and bullying. As a result of their work, they were invited to take on new leadership roles with the mayor's youth advisory council and as youth representatives for a local community organization. They have also recruited community leaders to serve on the planning committee for their upcoming Voices and Visions project. This project will be a series that gives space for community dialogue around youth issues.

Harnett County 4-H constructed community blessing boxes in response to their wanting to give back to their community and help families or individuals in need. Blessing Boxes are outdoor cabinets in public places with non-perishable food items, basic toiletries, and other commonly needed supplies. The 4-H participants constructed and stocked three boxes and strategically placed them around the county, particularly in areas with high needs. 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.

In Chatham County, the 4-H group wanted a project addressing food insecurity and community beautification. The youth massed 331 pounds of food, benefiting the two local food pantries in the countye CORA Food Pantry and the West Chatham Food Pantry. The youth group also completed phase 1 of the beautification plan for the Union Taylor Community Center. The beautification plan included building a raised bed around the center sign, planting perennial flower varieties, and installing two solar lights to illuminate the sign at night. With additional external funding, Chatham County United Way partnered with the Chatham County Extension Center. Future phases of the project will include landscaping around the community center building, constructing raised beds for a community garden, and installing rain barrels.

Haywood County was significantly impacted by flooding during Tropical Storm Fred (September 2021). In western North Carolina, communities were greatly impacted by damage estimated at more than $18 million for physical infrastructure alone. Haywood County 4-H partnered with Haywood Community College Early College to help youth participants become emerging leaders in Haywood County and allow them to complete environmental service-learning projects. The program partner was Haywood Waterways and Wildlife Services. The project involved about 30 young people enrolled in two courses in environmental sciences at Haywood Community College Early College. The youth mapped out economic, housing, healthcare, jobs, education, family, environment, community services, and human relations issues within the community. They worked on service projects and presented their findings and recommendations to local community leaders. Some service-learning projects were showcased during the county's Earth Day Celebration at Haywood Community College (April 2022). · Some of the immediate outcomes noted were youth gained experience and knowledge researching environmental issues within Haywood County; youth were engaged with community planning and setting future goals in addressing community issues; and youth gained confidence in public speaking.

Catawba County 4-H promoted YSF with their youth council and Junto's youth groups. The top issues that were raised during the YSF program were homelessness, community beautification, language differences, and access to healthcare. After much deliberation, the group of eight youth addressed language barriers as their community service project by offering English and Spanish language workshops to Latino families and other residents. They structured the program as a four-session series called "Breaking Language Barriers" (summer 2022). The youth actively assisted in the sessions – organizing the activities and assisting an ESL instructor who served as a "lead" teacher for the series. As a result of their participation in YSF, youth learned steps in project planning and appreciation for diversity in Catawba County. They also learned the following:

- ESL offerings that were available.
- Techniques for teaching the English language.
- How to create lesson plans for four sessions.
- Creating a plan to publicize workshops.
- Teaching youth and adults.

Vance County conducted the YSF program for their local Boys and Girls Club over the summer of 2022.

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

By engaging in their communities, youth are not only learning leadership skills that impact their futures. They are also positively impacting their communities by meeting various needs.

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.

Youth in underserved communities typically have little access to leadership development programs, which means many lower-income and minority children never have the opportunity to see themselves as leaders, grow their leadership skills, and have their voices heard. Youth Stepping Forward creates opportunities for rural and urban youth to learn leadership and public speaking skills. During the nine-week program, youth work together to address a shared community concern. 4-H agents and youth volunteers then help the youth execute community service projects. The program was piloted in eight counties in 2022 and involved 100 youth. The young people successfully addressed a number of community concerns, including food insecurity, youth violence, and caring for the natural environment.

Critical Issue

Improving Plant and Animal Agricultural Systems

Characterization of Galectins for Genome to Phenome Integration

Project Director

Mulumebet Worku

Organization

North Carolina Agricultural and Technical State University

Accession Number

7000376

Characterization of Galectins for Genome to Phenome Integration

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

This project addresses the need for increased definition of ruminant (cow,sheep,goat) Galectin (GAL) genes (LGALS) and phenomes in relation to resistance to parasites for precision breeding. Further the approach uses comparative genetics and Gal modulation using garlic as an alternative to antibiotics for sustainable food production.

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 effect of garlic extract on LGALS and GAL modulation in blood was evaluated ex-vivo and in vivo.

Objectives 1and 3: Three studies were conducted on sheep, one ex vivo, two in vivo trials. In the ex vivo trail blood was collected and incubated with garlic at 5 different concentrations (0,1, 10, 50, 100 ug/ul). In in-vivo trials the animals were drenched with garlic barrier for four weeks. Blood and fecal samples were collected for analyzing FEC, PCV, total cell count and viability and to analyze galectin gene expression, secretion and gut health.

Goat blood was tested with different preparations of garlic ex vivo. BoerXSpanish goats were treated with garlic barrier for 4 weeks. Body weight, BCS, FAMACHA, fecal and blood samples were collected. Fecal samples were evaluated for parasitic egg counts and microbial DNA. Blood was analyzed for PCV, total cell count and viability, differential WBC count, plasma protein concentration. Galectin concentration and LGALS gene expression and gut health were also evaluated. Species specific responses were observed. Both animal genetics and garlic preparation impacted the response to parasites and health indicators.

Objective 2and 3: Neutrophils were isolated from cow, sheep and goat blood and treated with garlic extracts. Changes in total cell count and viability, differential WBC count, plasma protein concentration were evaluated. In cow blood percent viability was highest in neutrophils treated with fresh garlic, compared to the aged garlic and control. Variability was observed in the response.

Objectives 1, 2 and 3: We've designed a total of 10 pair of primer sets by targeting all the exons of LGALS3 gene of sheep and goat. We extracted goat DNA from the blood samples collected on FTA card. Eventually we generated some data by sequencing. Data analysis and sequencing work is ongoing for goat galectins.

Thus studies thus far indicate that garlic extracts may serve as non-toxic modulators of animal health and contribute to the control of gastrointestinal parasites in small ruminants, improved body condition and enhanced immunity. Garlic supplementation has both systemic effects as well as effects on the diversity of gut microflora.

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

From the results obtained it has been proven that Garlic treatment has an effect on GIN levels, modulated Galectin secretion, and expression. There was a differential effect on structurally distinct Gal types. New knowledge has been gained to use Garlic as an immune booster and as an alternative to anti-helminthic. The phenotypic fingerprints uncovered regarding the effect of Garlic extract on Galectin gene expression have implications regarding gene function and regulation for use in sustainable animal production. In Animal production Galectin gene variation and Garlic extract preparation methods and dose need to be considered.

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

Studies of animal genetic variability, gene expression and modulation has implications to produce safe and abundant food for the growing population. The two-pronged approach of harnessing genetic variation and use of alternative natural immunomodulators and antimicrobials has animal and public health implications. It will aid in preventing disease and enhancing immunity without the use of antibiotics developing alternatives to antibiotic use in animals. Furthermore, Galectins and Garlic have been implicated in numerous human health complications this study will provide new knowledge for use of sheep, cattle and goats as animal models for human diseases. We are developing and testing reagents that will contribute to further research in this area. Training provided to students and personnel is contributing to a diverse well trained STEM talent pool. Producers benefitted from educational presentations and lab personnel attended trainings and workshops. Increased research capacity was gained including new equipment, personnel and collaborations. Contributed to new collaborative proposals and research foci eg NCTRACS planned R25 for the engagement of NC A&T students and faculty in the " bench" (T0) to "bedside" (T4) pipeline on advancing Translation Science.

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.

Challenges: The main challenge is Covid 19 – due to which the supply chains got impacted a lot. which delayed research timelines. We anticipate hiring a new research associate in the position previously held By Dr Hamid Ismail the process is in HR.

Professional Development: Dr. Md. Rasel Uzzaman post-doctoral scientist and Ms Priyankha Pande
PhD student have joined the team. Two students completed their thesis research, and we are collaborating on three funded undergraduate research projects on STEM talent preparations. Research training was provided to 5 undergraduate students and high school students in the college research apprenticeship program and through a collaboration with Syracuse University- CAREER Pre-College Program NCAT, Hampton University and Syracuse UNIVERSITY. Undergraduate research opportunities were provided in REEU-P4 program, Honors and intern/externship courses, Multicultural scholars program, Higher education challenge grants, and Savvy research leaders.

We have purchased new machines and organized and conducted workshops to learn new techniques. EX. Cytoflex. Micro array, Vet scan. Lab members have participated in multiple on line workshops including CITi training, R program, SAS, Artificial intelligence etc and are engaged in the Agricultural Genome to Phenome Initiative (AG2PI) field days "to assemble and prepare a transdisciplinary community to conduct AG2P research."

Dissemination:

1. Inupala, S.N., Jagana, S., Pande, P., Uzzman, M.R., Worku, M. (2022, October). Effect of fresh organic garlic on health indicators in St Croix sheep. Association of 1890 Research Directors, Inc. research symposium, Georgia, Atlanta, USA. (Poster)

2. Inupala, S.N., Jagana, S., Pande, P., Uzzman, M.R., Worku, M. (2022, Jun 26-30). In-Vitro effects of Garlic on secretion of structurally different Galectins in sheep blood. ASAS-CSAS Annual Meeting, Oklahoma City, OK, USA. (Poster)

3. Inupala, S.N., Jagana, S., Pande, P., Uzzman, M.R., Worku, M. (2022, Jun 26-30). Effect of Garlic Extracts on Galectin Protein Secretion in St.corix Sheep Blood. ASAS-CSAS Annual Meeting, Oklahoma City, OK, USA. (Poster)

4. Inupala, S.N., Jagana, S., Pande, P., Uzzman, M.R., Worku, M. (2022, September 7-9). Garlic for sustainable production of hair sheep diversified production in the US. Next-generation Sustainable Technologies for Small-scale Producers. NC A&T State University, NC, USA. (Poster)

5. Jagana, S., Inupala, S.N., Pande, P., Uzzman, M.R., Worku, M. (2022, Jun 26-30). Modulation of Goat Plasma Proteins Using Different Preparations of Garlic. ASAS-CSAS Annual Meeting, Oklahoma City, OK, USA. (Poster)

6. Jagana, S., Inupala, S.N., Pande, P., Uzzman, M.R., Worku, M. (2022, Jun 26-30). Effect of Garlic Barrier on Fecal Egg Counts and Plasma Proteins. ASAS-CSAS Annual Meeting, Oklahoma City, OK, USA. (Poster)

7. Jagana, S., Inupala, S.N., Pande, P., Uzzman, M.R., Worku, M. (2022, September 7-9). Effect of Garlic on Meat Goat Production. Next-generation Sustainable Technologies for Small-scale Producers. NC A&T State University, NC, USA. (Oral)

8. Jagana, S., Inupala, S.N., Ismail, H., Worku, M. (2022, October). Detection of Fecal Calprotectin as a Biomarker in Goats. ARD Symposium, Atlanta, Georgia, USA. (Poster)

9. Pande, P., Inupala, S.N., Jagana, S., Uzzman, M.R., Worku, M. (2022, September 7-9). Differential effects of garlic for use in non-chemical dairy production. Next-generation Sustainable Technologies for Small-scale Producers. NC A&T State University, NC, USA. (Poster)

10. Pande, P., A-Fremah, S., Worku, M., Jagana, S., Inupala, S.N., Deng D. (2022, September 7-9). Exposure to environmental pollutant Genx chemical modulates innate and adaptive immunity genes in Cow neutrophils. Next-generation Sustainable Technologies for Small-scale Producers. NC A&T State University, NC, USA. (Oral)

11. Uzzman, M.R., Edea, Z., Islam, R., Kim, K. S., Worku, M. (2022, September 7-9). Identification of single nucleotide polymorphisms for small ruminants' health and adaptation. Next-generation Sustainable Technologies for Small-scale Producers. NC A&T State University, NC, USA. (Poster)

12. Uzzman, M.R., Edea, Z., Islam, R., Kim, K. S., Worku, M. (2022, Jun 26-30). Analysis of Galectin Gene Variants from Diverse Sheep and Goat Populations Genotyped with the Illumina Beadchip. ASAS-CSAS Annual Meeting, Oklahoma City, OK, USA. (Poster).

13. Worku M educational outreach presentation on small ruminant production and Goat research 35 th annual Small farms week: Goat research seminar to producers March 23 2021.

14. Project progress has been shared with members of three multistate projects addressing genomics(NRSP-8), goats(SSC-81), Mastitis (MW-635).

15. Thesis:Effect of Garlic Barrier on Health, Hematological Parameters, Gut Health and Gene Expression

in Boer X Spanish Goats. By Sowmya Jagana, Worku Advisor

16 Thesis:Modulation of structurally different galectins, health parmeters and gut health using garlic in ST Croix Hair sheep. BY SreeNavay Inupala. Worku Advisor

Dissemination (Accepted):

Abstract Titles for ASAS SOUTHERN SECTION MEETING, January 21 - 24, 2023, Raleigh, North Carolina.

1. Evaluating the Effect of Garlic on the Gut Health of Meat Goats -Sowmya Jagana

2. Response of Ruminant Neutrophils on Fresh Filtered Garlic Preparation- Dr. Md. Rasel Uzzaman

3. Evaluation of Effects of Garlic on Health Parameters and Gut Health in St. Croix Sheep- SreeNavya Inupala

4. Exposure To Environmental Pollutant Genx Chemical Modulates Innate and Adaptive Immunity Genes in Cow Neutrophils – Priyanka Pande

Development of sensor technology for the early detection of plant disease

Project Director
Ralph Dean
Organization
North Carolina State University
Accession Number
7000727

Annual Result: Development of sensor technology for the early detection of plant disease

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

Crop losses due to pests and pathogens remain a major challenge to food safety and security. Our project aims to provide a remote, autonomous, networkable early disease detection platform enabling more timely and effective disease management, which will reduce crop losses (increase yields) in production and storage.

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.

Plants when stressed either through wounding or disease release volatile organic compouds (VOCs), such as the smell of fresh cut grass. The bouquet of VOCs released reflects the type of pathogen or pest. We have further designed and refined the electronic sensor by adding additional functionality to detect different classes of VOCs and developed computer analyses/deep learning algorithms to descriminate particular VOC signatures. We have shown that we can detect and discriminate different combinations of VOCs and recognise diseased plants before symptoms appear in controlled environments.

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

Our ability to detect, sniff-out, infected plants and crop products before the produce is destroyed by disease will of major benefit to farmers and consumers. Our ability to detect disease prior to symptoms even in controlled environment conditions is a major step forward to demonstrate these sensors can work in real world environments. Detection not only alerts farmers of a potentially serious problem, but will allow them to mobilize measures to address the problem in a timely manner.

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

Increasing food production is a ever increasing global issue. Thus cost effective measures through early disese detection in crop production or anywhere in the food supply chain that reduces chemical inputs (less spraying), reduces labor costs and reduces losses will be of benefit to society as a whole. Society gains from more, cheaper, higher quality, sustainably produced crops.

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.

DESIGNED AND ENHANCED ELECTRONIC SENSOR FOR EARLY DISEASE DETECTION IN CROPS: Crop losses due to pests and pathogens remain a major threat to food safety and security. To address this problem, NC State researchers are working to provide a remote, autonomous, networkable early disease detection platform that will enable more timely and effective disease management in order to increase crop yields. Researchers have designed and refined an electronic sensor that can detect different types of volatile organic compounds (VOCs), substances that plants release when they are stressed due to damage or disease. They have also enhanced this sensor's ability to detect different classes of VOCs and developed computer analyses and deep learning algorithms to further decode these VOC signatures. Interpreting these signatures can help identify the type of pathogen or pest that is damaging plants, potentially even before symptoms appear. This ability to detect pathogens and diseases early will be of major benefit to farmers and consumers by reducing crop losses, limiting the need for chemical pesticides, and reducing labor costs associated with pest and disease control.

delete

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

x

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.

x

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

x

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

x

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.

x

Evaluating Abiotic Stress in Specialty Crops Using Digital Agriculture Technology

Project Director
Gregory Goins
Organization
North Carolina Agricultural and Technical State University
Accession Number
7000335

Evaluating abiotic stress in specialty crops using digital agriculture technology

Final Result

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

The overall goal of this research project is to advance fundamental knowledge on physiology of specialty crops under abiotic stress conditions using sensor technology. The understanding of how combination of stressful factors impact crop yield is a priority for sustainable crop management. Therefore, this project is focused on providing new insights into plant physiology, and its impacts on yield and quality of specialty crops such as CBD hemp and green leafy vegetables.

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 project completed two objectives. The major activities conducted for each objectivel are described below:

Objective 1: Plant physiological parameters such as photosynthesis, stomatal conductance, transpiration were measured using portable photosynthesis machine (i.e. LICOR 6800) in two hemp cultivars (i.e. Therapy and Spectrum) grown under four organic nitrogen amendments (i.e. compost, cover crop, compost + cover crop, and control). Measurements were conducted three times (i.e. early vegetative, late vegetative, and floral stage) throughout the growing season. Our data showed that compost and combination of cover crop and compost has the greater photosynthesis compared to other treatments. The decline in leaf photosynthesis from early vegetative to floral stage suggests the possibility of resource allocation from vegetative to floral stems.

Objective 2: Plant physiological parameters such as photosynthesis, transpiration, and stomatal conductance were measured in three lettuce cultivars (i.e. Rouge D'Hiver, Black Seeded Simpson, and Tango) at 20°C (control) and after applying cold temperature treatments (i.e. -4°C and -5°C) for an hour in the freeze chamber. Our results showed that cold stress resulted in lower and negative photosynthesis under cold temperature treatment. In contrast to photosynthesis, transpiration rate and stomatal conductance increased significantly under cold temperature treatments. Overall, this study showed that Rouge D'Hiver has better cold stress tolerance compared to other two lettuce cultivars.

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

One undergraduate student (female) was hired during the course of this project. This student was trained on how to utilize digital agricultural technologies such as various types of sensors to understand and monitor the impacts of abiotic stresses on plant physiological processes. The student presented her research at local, national, and international conferences and also received second place for best undergraduate research poster at the college level during CAES student showcase of excellence. The student was also selected to present her research in front of UNC Board of Governors and Dean's advisory board.

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

The scientific community (Scientists, Post-doctorals, Graduate and Undergradaute students) interested in the use of latest digital agricultural technologies for crop production will benefit from this project. Additionlly, farmers who are willing to adopt digital technologies to improve crop production and quality will be interested in this project. Other interested group would be the companies that are marketing digital sensors for agricultural usage.

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.

Publications/Presentations

Atoloye, I. A., Adesina, I. S., Sharma, H., Subedi, K., Liang, C. L., Shahbazi, A., & Bhowmik, A. (2022). Hemp biochar impacts on selected biological soil health indicators across different soil types and moisture cycles. PloS one. 17(2), e0264620.

Lee, Kenene., Goins, Gregory., Bhowmik, Arnab., & Sharma, Harmandeep.(2022, Sep 07). Physiological response of floral hemp varieties grown under regenerative practices. CAES student showcase of Excellence, NCA&T (Second Place in Best Undergrdaute Research Poster)

Lee, Kenene., Goins, Gregory., Bhowmik, Arnab., & Sharma, Harmandeep.(2022, June 23). Physiological response of floral hemp varieties grown under regenerative practices. CAES's Small Farms Field Day, NCA&T (Poster)

Lee, Kenene., Campbel, Morgan., Goins, Gregory., Bhowmik, Arnab., & Sharma, Harmandeep. (2022, April 2-5). Biosequestration potential of CBD hemp varieties using Digital Technology. Association of 1890 Research Directors Biannual Conference, Atlanta, Georgia (Poster)

Sharma, Harmandeep., Randle, William., Zitawi, Baker.,& Goins, Gregory. (2021, November 08). Impacts of cold stress on plant physiological processes in lettuce cultivars. Annual meeting of Crop Science Society of America, Salt Lake City, Utah (Poster)

Sharma, Harmandeep., Campbel,l Morgan., Goins, Gregory., & Bhowmik, Arnab. (2021, November 08). Photo-sequestration potential of organically grown floral hemp in North Carolina. Annual meeting of Crop Science Society of America, Salt Lake City, Utah (Poster)

Integrated Study of Micropropagated Ginger on Production Systems and Health Benefits

Project Director

Guochen Yang

Organization

North Carolina Agricultural and Technical State University

Accession Number

Integrated Study of Micropropagated Ginger on Production Systems and Health Benefits

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

Ginger is exclusively produced in Hawaii that can only meet 20% of the demand. Such situation creates an excellent niche market opportunity for small farmers to grow baby ginger because of its consistently high price of $15-20 per pound for the past 10 plus years. Seed ginger availability and quality have been problematic for many years, thus a major limiting factor for ginger production in NC and other states. In order for ginger to become a viable commodity, a practical and affordable seed source independent from Hawaii is needed. This project is to develop the best baby ginger production system with good bioactivity and health benefits and to reduce the dependence on Hawaii ginger seeds by developing an efficient micropropagation system for mass production of ginger plantlets, thus to help solve this significant seed ginger sourcing issue.

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.

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We are evaluating seven ginger cultivars plus tissue culture (TC) ginger generations on growth and yield in greenhouse and high tunnel settings at the University Farm. Upon harvesting, rhizome (root) samples will used for extract preparation for bioactivity and health benefits evaluation. We have already initiated and developed micropropagation process with all ginger cultivars in the lab, and fine tuning the process for mass production of ginger seedlings. Phytochemical composition analysis is being conducted for ginger leaf samples, and pending rhizome (root) samples upon harvest. Growth data are being collected on number of stems per seed plant or TC ginger seedling, stem diameter, and stem length (plant height). Ginger rhizome (root) yield will be collected and evaluated per seed plant or TC ginger seedling upon harvesting. We are working closely with our stakeholders, small and limited resource farmers in different counties, and conducted workshops for county extension agents, farmers, and general public who is interested in ginger production. This ginger project was an integral part of the annual Small Farm Field Day with about 250 participants for 2022. Farmers are adopting our research findings to grow their own gingers, and requesting our micropropagated ginger seedlings after witnessing our research. Our micropropagation has real potential to help solve ginger seed sourcing issues for the mainland states of the U.S. in near future.

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

We designed this project with collaborative efforts specifically targeting the needed niche market and alternative cash crop to help solve the significant seed ginger sourcing issue for stakeholders, particularly the small and limited resources farmers. This project is a meaningful collaboration between plant and animal health research and cooperative extension because of its requirement of three complementary expertise areas in micropropagation, ginger production and outreach, and bioactivity and health benefit evaluation. This project is an integral part for the annual small farm field day that attracts county extension agents, farmers and general public. While showcasing our research findings via such project activities, we also learn issues facing our stakeholders. Our project could serve as a collaboration model to help our stakeholders. This project also serves as an education tool by providing an experiential learning platform for students, thus to enhance education capacity in training students. Our micropropagation protocol has real potential for help solve the seed ginger sourcing issue for the mainland states of the U.S. and for intellectual property, thus would enable economic development, in addition to be applicable to other niche market cash crops with similar characteristics

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

We place our research in real society situation (stakeholders' farm condition) by working closely and strategically with our stakeholders from different counties in North Carolina including Buncombe, Franklin, Guilford, Stokes, Union, and Warren Counties. We are also working with AgrAbility Program. Our ginger research has some direct and meaningful impacts on our stakeholders, small and limited resource farmers. Here is a direct impact quote of Plum Granny Farm, a small and USDA certified organic farm in Stokes County NC: "Dr. Yang's tissue culture ginger research plants really helped us last year! Due to COVID-19, we faced a serious labor issue like most other small farms in the state. We had very little help, and some of our crops suffered. The seed ginger we ordered was mostly diseased and wouldn't sprout so we eventually dumped it all with a total loss. Because of our collaboration with Dr. Yang, he provided us with some ready-to-go tissue culture ginger seedlings.

We planted and harvested from a little over 50 seedlings for teen-baby ginger with only about 3-months growth. Thanks to these plants, we were able to deliver ginger to our PlumFresh subscribers. Based on our observations, we see terrific potential of tissue culture ginger to help provide a reliable source of ginger plants for small farms across the country."

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.

Our project progress is right on target as planed. Research findings have been shared with large science community at national scienctific conferences, and also disseminated on a on-going basis with our stakeholders, small and limited resources farmers via various venues, such as phone calls, e-mails, text messages, in person visits, small farm field day, small farm week, and workshops, etc. Our project also serves as an experiential learning platform for students at all levels (undergraduate, MS and doctoral students) who are actively engaged in this interdisplinary project for their training in critical thinking, communication and displine expertise. We will continue to closely follow our project plan as outlined.

Agronomic Crop Production Systems

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

Annual Result: Agronomic Crop Production Systems

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

Row crops contributed over $3 billion to North Carolina agricultural sales in 2021. Corn, soybeans, and small grains (wheat, barley, or oats) are grown in most counties in the state, with cotton and peanuts being confined to fewer, better-suited areas. In 2022, North Carolina agronomic crop producers planted approximately 4.6 million acres of row crops, with the highest acreage planted with soybeans, corn, wheat, and cotton ranked in order respectively.

Row crop producers face technological, biological, and environmental challenges that impact crop yield and ultimately the profitability of their farm operations. Technological challenges that can impact crop yields include decisions about which variety to plant, which fertilizers to use, and decisions about purchasing new products and adopting technology on the market. Biological challenges include the preventative measures producers take to prevent weeds, pests, and diseases from causing significant damage to annual yields. Producers use research-based information and experts for guidance and to diagnose problems. Producers face environmental challenges, including problems associated with soil erosion, soil fertility, and water quality as well as problems caused by a changing climate. They must address soil and water issues to prevent declines in production.

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 specialists used applied research and on-farm and official variety testing to develop new varieties, products, technology, and research-based agronomic crop best management practices (BMPs) to support growth in row crop production and assist growers in addressing their technological, biological, and environmental challenges. Extension specialists and agents transferred knowledge of these innovations and practices to producers through Extension publications, websites, meetings, workshops and field days, research and demonstration plots, on-farm consultations, webinars, and videos. Educating growers on research-based best practices equips them with the knowledge to adopt practices that are correlated with increased yields.

- NC State Extension specialists disseminated new agronomic crop information and best practices through the publication of over 400 Extension publications to educate Extension agents, growers and members of industry.

- NC State Extension agents used **social media and mass media** to provide educational information to crop producers. Extension agents reached over 1.3 million growers through social media and websites and reached over 5.2 million producers through mass media such as television, radio, and newspapers. Extension specialists posted educational content on social media approximately 1,000 times reaching nearly 70,000 producers created 150 newsletters reaching over 10,000.

- NC State Extension specialists maintained 15 agronomic crops, pest, and disease **web portals** that were viewed nearly a half a million times during 2022.

- Extension agents delivered close to 2,000 **in-person and virtual training sessions** to over 40,000 growers on agronomic crops, and over 13,000 additional growers attended training provided by Extension specialists. Over 15,000 pesticide applicators received continuing education credits. Nearly 200,000 growers were provided with **technical assistance**.

In 2022, NC State Extension brought together growers, researchers, and agribusinesses to share research-based insights and provide continuing education credits through **field days, expos, and production meetings**. The **Northeast Ag Expo** was particularly successful, with Extension agents across 6 counties working with several partners to carry out and share variety performance research for corn and soybean crops. Expo participants represented over 690,000 acres and enjoyed an estimated $6.5 million in added crop value thanks to education and resources provided by the Expo.

During the 2022 **Northeast Ag Expo Small Grains Field Day**, 116 attendees were provided with education on grain marketing, profitable yield maximizing wheat management practices, and best practices for disease, weed, and nitrogen management. With help from local and state partners, the Small Grains Field Day helped growers representing 97,975 acres of cropland and 20,375 acres of small grains. Growers reported an average best practice adoption rate of 59% based on all information provided at the field day. When asked if they had benefited from previous small grains field days, growers representing a total of 10,625 acres reported an average yield increase of 6.7 bushels per acre, valued at $569,855.

To support growers in 2022, Extension in Camden County created **research-based programs and educational materials** tailored to local agricultural needs, delivering these resources via on-farm consultations, two collaborative regional field days, production meetings, variety demonstration trials, pest monitoring, and the Camden Crop News newsletter series. By adopting Extension recommended best management practices spanning nutrient management, conservation, production, cultivar selection, pest management, business management, and marketing, growers increased their net income by over $3.3 million. **As a leader in experiential education, NC State Extension equipped farmers to effectively transfer best management practices into practical applications.**

Herbicide resistant weeds are becoming a significant problem in the coastal plains of North Carolina. Extension specialists and agriculture agents have worked together to gather and provide meaningful management techniques to the agricultural community. Resistant weed management education for producers in Northampton County was provided through **production meetings, on-farm tests, newsletters and on-farm visits**. Follow-up survey results indicate twenty-three growers representing 22,990 acres adopted Extension recommended weed management practices for the weed marestail and estimated the value of the information gained at $1,301,852 and twenty-five growers representing 26,460 acres adopted Extension recommended weed management practices for the weed palmer amaranth and estimated the value of the information gained at $1,310,666.

In 2022, NC Cooperative Extension also enhanced soybean crop health and grower profits by **delivering new research-based insights** for insecticide application against stink bugs, a critical soy crop pest that caused over $8 million in damages in 2017. Thanks to this Extension research being shared at numerous grower meetings statewide and via the NC State Extension web portal system, growers were able to avoid unnecessary sprays, reducing treatment costs and avoiding killing beneficial insects. Assuming that 15% of NC soybean acres were treated according to Extension recommendations, growers secured an estimated savings of over $1 million. **NC State Extension provided solution-driven research and technology to empower growers to make better-informed weed and pest management decisions.**

As a result of NC State Extension programs, over **25,000 crop producers** increased knowledge, attitudes, and/or skills related to best management production practices; pest/insect, disease, weed, wildlife management; financial/farm management tools and practices; alternative agriculture, bioenergy, and value-added enterprises; and as a result of NC State Extension programs, approximately **13,000 crop producers** adopted best management practices, including practices related to nutrient management, conservation, production, cultivars, pest management, business management, and marketing.

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

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. The 8 Extension Centers making up the ~~Northeast Ag Expo team~~ coordinated 6 corn variety demonstrations in partnership with local growers and seed companies. Given that an estimated 85% of local growers utilize Northeast Ag Expo variety demonstration trials when selecting hybrids, and given that the top yielding hybrids in the trial increased yield by an estimated average of 7.4 bushels per acre, these demonstrations benefited approximately 64,000 acres, resulting in an added value of over $2.9 million. In addition, Extension in Davie County planted a corn variety trial on a local farm, replicating the trial in four surrounding counties. Tests of 14 hybrids with diverse maturity dates revealed the top yielding varieties that could increase annual gross profits by over $5.4 million countrywide, based on an estimated 7,000 acres of corn planted.

Cotton seed is one of the costliest inputs in cotton production with new varieties entering the market very quickly, with very little supporting data from the pre-commercial stages. To assist with variety selection, the **NC On-Farm Cotton Variety ~~Evaluation Program~~** consists of 16 to 17 trials in producers' fields across the state annually. 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 2021 on-farm program resulted in an estimated economic impact of over $31.6 million to over $68 million, and the potential impact of the 2022 program is estimated at over $20 million to over $43 million. The estimated value of the **NC State Cotton Planting Conditions Calculator**, which growers use to make variety decisions for their farms, is estimated at $795,000 annually.

Web-based grains and cotton tools developed by Extension specialists provide varietal recommendations based on anticipated climatic stress, planting date, crop maturity, traits and more to enhance crop performance. Extension in Craven, Carteret, Pamlico, and Jones counties coordinated with NC State faculty to provide **training in the use of these tools**. This training and use of the tools helped corn and soybean growers representing an estimated 3,950 acres switch to a higher-yielding variety, a more suitable soil type, and/or an improved strategy for managing climatic stress. Using an average value increase of $130 per acre, these improvements secured an additional $5 13,500 annually for growers.

To help peanut growers compare data on variety performance, an NC State research group created a **~~web application~~** that offers over a decade of historic yield data for various peanut varieties across multiple locations, providing at-a-glance breakdowns of each cultivar's name, parentage, and genetic traits. This online tool is just one small part of ~~NC State's peanut~~ breeding program, which is constantly working with Extension to deliver actionable, research-based approaches to crop protection, helping growers minimize losses and reduce the use of crop protection chemicals.

Each year approximately 41% of the 141 farms in Chowan irrigate their crops by pulling irrigation water from the Chowan River, Albemarle Sound, or small creeks and ditches that are connected to the River or Sound. As this water is brackish, the salinity in the water can sometimes spike, especially in years of dry weather. Salty water can cause significant damage in the form of salt burn to the foliage and roots of sensitive crops like peanuts. It can also cause long-term damage to the soil and can decrease the water holding capacity and decrease subsequent crops ability to draw water out of the soil. Chowan has been in drought conditions since April 2022 which has caused the Salinity in the River and Sound to increase to levels not seen in years. The Extension agriculture agent has been **measuring salinity levels** in the water at different points in the River and Sound the county then **sends notices to farmers** about the salinity levels and how much irrigation water they can use, at the measured salinity, before they cause significant damage to their crops. As peanuts are the most salt sensitive crop to salinity that farmers are growing, most can irrigate only about two inches of water before they must wait for rainfall to mitigate the salt accumulation from their irrigation systems. Irrigating more than that can cause total crop loss. This program has saved approximately 1,353 acres of the 3,300 acres of peanuts from significant salt damage if not complete crop loss. At approximately $450/ton and an average yield of 1. 97 tons/a, this program has saved peanut farmers approximately $1,199,434.50. **Empowering NC growers by providing on-demand information and tools to improve decision-making is just part of how we are growing the future of agriculture in North Carolina.**

North Carolina is the fifth-largest peanut-producing state. In 2021, North Carolina farmers grew 452 million pounds of peanuts on 113,000 acres. Estimating peanut maturity and digging at the optimal time is a pivotal production decision that impacts peanut profitability. Key factors such as weather, field condition, health of the peanut vines, and size of the grower's operation are accounted for when helping to determine this important decision. Flavor, grading, milling quality and shelf life all depend on peak maturity. Greater percentages of large or undamaged kernels mean crop premiums to farmers. But because the plant is an indeterminate grower all kernels do not mature at the same time. In addition, the kernels develop in pods that grow beneath the soil surface. Identifying optimal harvest maturity can be a challenge. Extension Agents across 10 counties helped peanut growers use a method called **pod blasting to test the maturity of their peanut crops**, ensuring optimal maturity at harvest and increasing yields by as much as 45 pounds per acre per day and enhancing shelf-life for roasted in-shell peanuts. Using a technique to remove the outer layer of the pod and grouping the pods together by color the best time to harvest can be estimated. Growers still have to make the final decision when to dig based on the weather, disease pressure, labor and

machinery availability etc. Harvesting too early or too late costs the grower income. These efforts helped improve peanut yields across over 30,000 acres statewide, securing an estimated added value of over $3 million. **Improving NC's agricultural economy through increased yields is just part of how we are growing the future.**

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

Nitrogen fertilizer is the costliest input in corn cropping systems. During 2022, global supply of nitrogen fertilizer was greatly influenced by European conflicts. This led to delays and supply shortages and record high fertilizer prices for growers across the country and in turn impacting food prices for the public. Since nitrogen fertilizer is a key component in the successful production of corn grain in North Carolina, it was essential that growers utilized their limited supplies efficiently to remain economically sustainability during 2022. Reducing nitrogen fertilization to corn not only protects the environment from unwarranted excess nitrogen that degrades water quality through eutrophication, but it also increases profit for the producer. NC State Extension researchers demonstrated that most grower nitrogen rates could be reduced by 25% without impacting yield. Therefore, to protect the environment and increase profit, growers need to reduce nitrogen rates to corn.

To reduce nitrogen fertilizer use while maintaining corn yields, NC State is developing new technologies to apply nitrogen fixing bacteria to the corn, providing some of the required nitrogen. Unfortunately, little to no work has been done to determine how effectively these technologies fix nitrogen under field conditions or their potential environmental impacts. To address this issue, Extension partnered with NC State researchers to conduct 9 field trials, 3 of which were highlighted at various expos and field days. At these meetings, over 500 corn growers were provided with data and education on how to maximize utility of these new technologies. The trials demonstrated that the studied bacteria can indeed fix nitrogen in NC corn fields. When used in the right environment and with the correct careful handling, the materials can save corn growers $0.25 to $0.50 per pound of nitrogen and reduce their carbon footprint and water contamination rates. Reducing the use of N fertilizer by 40 lbs per acre on 910,000 corn acres in North Carolina can significantly reduce the carbon footprint of growing corn and can reduce water contamination in this state. The field trials also revealed that growers in the Coastal Plain are less likely to see a significant impact from these technologies, thus by informing corn growers in this region of the limitations of this technology, an estimated $500,000 could be saved in wasted equipment costs.

Agriculture Extension Agents in Craven and Pamlico Counties conducted replicated field trials in three counties. These trials were conducted over a two-year period (2021-2022) and examined the relationship between various nitrogen rates and yield, and their comparison to university recommendations tied to soil type and realistic yield expectations. University Extension specialists assisted with field trial harvest and with data analysis. Results were shared with growers and professional crop consultants through on-farm field events, during winter production meetings, and through regional news articles. From these efforts, Extension agents were able to demonstrate that corn nitrogen needs vary by location and soil type, and that growers who utilized university-based recommendations had the potential to lower excessive nitrogen rates and reduce cost if their current practices exceeded recommendations. As a result, 67% of growers surveyed during a 2022 winter production meeting expressed their intent to utilize university-based recommendations during the growing season, with 50% reporting the potential to reduce nitrogen inputs on marginal lands that have less yield potential. Additionally, several growers approached Extension agents during the 2022 season to discuss this research and made adjustments to current practices.

NC Extension Centers of Craven, Carteret, Pamlico and Jones Counties coordinated with NC State faculty to provide research data supporting reduced nitrogen rates to corn. Replicated plots were established in Craven, Pamlico and Duplin. Statistical analysis of harvest data from these plots showed no significant difference between 25% below the grower nitrogen rate and the grower's nitrogen rate. Rates 25% above the grower rate was only significantly higher at one location experiencing drought conditions. Articles addressing this issue were provided on Extension web pages and in newsletters. Based on survey results at meetings and in direct communications with growers, 63% of corn producers stated they would consider reducing nitrogen rates to corn. Personal observation and interviews with growers show that 18% did so in 2022 by reducing nitrogen rates 25% or more on 3,100 acres. Based on current nitrogen prices and a reduction of 25 lbs./ac of nitrogen on these acres, this saves $75,000 for producers and reduces excessive nitrogen concentration to surrounding waters.

Nutrient pollution is a result of excess nitrogen and phosphorus into the air and water. A range of health effects has been associated with ingesting nitrate-contaminated drinking water including methemoglobinemia, various cancers, adverse reproductive outcomes, diabetes, and thyroid conditions. NC State Extension has developed new technologies, conducted field trials and producer training, that has led to corn growers reducing nitrogen rates ultimately resulting in a reduction in grower dependance on fertilizer imports, lower food prices, reduced our carbon footprint and reduced levels of nutrient pollution. **Protecting NC's agriculture and environment through stewardship is just part of how we are growing the future.**

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 2022 to facilitate the use and transfer of new research-based knowledge:

- Brassica Crop Agent Training
- Considerations for Low Nicotine Tobacco Production
- Corn, Soybean, and Wheat Variety Placement
- Cotton & Peanut Agent Training Field Day
- Drones in Ag: Regulations, Technology and Uses
- Fiber Hemp Agronomics and Market Update
- Flue-Cured Tobacco Agent Training
- Grains Agronomic Program Team Conference
- Herbicide Injury Symptoms, Diagnosis & Response
- Micronutrients for Row Crops in North Carolina
- Peaches & Cream: Economic Updates for Specialty Crops & Dairy
- Planning a Successful On-Farm Research Trial
- Seedling Weed Identification for Row Crops
- Sensors, Data, and Controls for On-Farm Studies
- Technology Adoption and Open Source Tools for Soybean Producers
- The Unusual and Obscure: Weeds in Row Crops
- USDA Federal Regulation and Industrial Hemp Production in NC

- What To Do If You Suspect Herbicide Contamination?

- Winter Cotton & Peanut Agent Training

The following **Factsheets and Peer Reviewed Extension Publications** were developed by Extension Specialists for dissemination of research-based information to Extension agents, growers, and other stakeholders.

- 2023 North Carolina Agricultural Chemicals Manual (AG 1)

- North Carolina Soybean Production Guide (AG-835)

- Growing Cotton for Ornamental, Educational, Non-Commercial, or Atypical Commercial Reasons in North Carolina (AG 923)

- Utilizing the NC State University Cotton Planting Conditions Calculator and the NCDA&CS Cotton Seed Database to Make Wise Planting Decisions (AG 924)

- Utilizing the North Carolina Department of Agriculture and Consumer Services Cotton Seed Quality Testing Program to Make Better Planting Decisions (AG 925)

- Optimizing Floral Hemp Biomass through Proper Transplant Timing and Density (AG 938)

- Size Matters: Accounting for Hemp Seed Size When Calibrating Your Grain Drill

- Sting Nematode in Corn

Extension specialists contributed to solving regional and national issues through **multi-state collaborative Extension efforts**. Some multi-state programs NC State Extension participated in included:

- SCC-33. National Variety Testing. Organized an in-person and virtual meeting in Fort Lauderdale, FL Feb 10-14, 2022 with over 40 participants

- Investigation of Alternative Energy Options for Flue-Cured Tobacco Barns collaboration with Virginia Tech Southern Piedmont Center, Blackstone VA.

- Collaboration for regional training for extension agents with flue-cured tobacco responsibilities across North Carolina, Virginia, South Carolina, and Georgia.

- Beltwide applied research projects concerning cotton seed quality along with our counterparts in other cotton producing states who are members of the Extension Cotton Specialists Working Group.

- Southern Cotton Growers Inc consists of members from each Southeastern states cotton boards to develop regional initiatives for cotton seed quality testing and ongoing research updates.

- Collaboration with Tennessee, Kentucky, Virginia, and Arkansas on the Multi-State Regional Soybean Database.

- National 'Science for Success' team comprised of University Soybean Extension Specialists from >15 states across the US who collaboratively deliver Soybean Best Management Practices to growers across the US.

- Collaborated with Virginia Tech and Clemson on peanut pest management and variety testing projects.

- Collaborated with University of Georgia on fertility and plant growth regulation projects.

- S-1084 focus on hemp (floral, grain, fiber) research and extension development.

- Multiple multi-state field trials, which were highlighted at Extension events. One trial, focused on understanding the genetics of flowering time in hemp, is a collaboration with Cornell. The second trial is a screening of newly developed fiber and grain genetics and is a collaboration with Cornell, University of Kentucky, Texas A&M, and the University of Florida.

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.

Extension agents delivered close to 2,000 in-person and virtual training sessions to over 40,000 growers on agronomic crops, and over 13,000 additional growers attended training provided by Extension specialists. Over 15,000 pesticide applicators received continuing education credits. Nearly 200,000 growers were provided with technical assistance. 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

Annual Result: Animal Production Systems

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

The food animal industry represents approximately 70% of North Carolina's agricultural economy with all 100 counties producing some type of animal-sourced product. 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. North Carolina has nearly 8 million hogs, 785,000 cattle, and 916 million broilers (chickens grown for meat). The state is ranked #1 for production of all poultry species and #2 for overall hog and trout production nationally. In addition, small ruminants remain a key source of meat for consumers. In fact, over the last 10 years, there has been an increased interest in small ruminant production, especially meat goat production.

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. Across the 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.

NC State Extension specialists used applied research and on-farm testing to develop innovative products, technology, and research-based animal science best management practices (BMPs); support increased profitability of animal agriculture, equine, and forage producers; and address consumption demands and reduce environmental damage while protecting animal health and welfare. Extension specialists and agents delivered information on these innovations and practices to producers through Extension publications, websites, meetings, workshops and certification programs, on-farm consultations, webinars, videos, and newsletters. Extension also led the development of new disease and waste management plans as well as novel technologies to enhance animal health.

- NC State Extension specialists disseminated new animal science information and best practices through the publication of 85 **extension publications** to educate Extension agents, producers, and members of the industry.

- NC State Extension specialists maintained 20 livestock, aquaculture, and poultry-related **websites**. The animal agriculture production websites maintained by Extension specialists were viewed over 250,000 times disseminating up-to-date research-based information and best practices.

- Extension agents reached nearly 600,000 producers through **social media and websites** and reached approximately 12 million producers through **mass media** such as television, radio, and newspapers. providing animal and poultry science educational information.

- NC State Extension specialists produced 70 **on-demand educational videos** on animal and poultry science-related topics that were viewed 10,000 times.

- Approximately 25,000 participants attended **training** provided by Extension livestock agents, and an additional 10,000 participants attended training provided by Extension specialists.

- 65,000 individuals were provided with technical assistance through **on-farm consultations** provided by Extension livestock agents.

To support cattle producers in the face of out-of-date and closed livestock exchange facilities, Extension in Union County partnered with a cattle panel dealer to develop a **removeable cattle sale system** for the Union County Agricultural Complex. This system was designed based on feedback from local producers and tailored to the unique needs of the local community,

and it was used for the first time in December of 2022 for a performance tested bull sale that grossed $187,500 and attracted over 200 people. One producer described the sale set-up as “the best thing that has happened for the Union County cattle industry in a long while.” The system also received praise from consigners, and several other sales have reached out to secure dates for their events.

To help preserve flock health, protect natural resources, and maximize the agricultural value of poultry waste by-products, in Randolph County, Extension **built an advanced composting technology (ACT) system** and invited local growers to see the machinery in action, educating them about how ACT systems can improve the efficiency of composting. This field day demonstration attracted 20 attendees, including current and potential poultry producers, agricultural lenders, broiler company representatives, poultry Extension agents, and a local livestock agent.

To address a 2022 uptick in highly pathogenic avian influenza (HPAI) and mitigate harm to NC’s nearly $40 billion commercial poultry industry, Extension collaborated with industry partners to encourage producers to establish and follow strict biosecurity protocols. Extension helped organize conference calls between producers and flock supervisors and a veterinarian, providing answers to pressing questions about the emerging situation with HPAI in and around NC and **providing advice to help keep HPAI out of commercial flocks**. These conference calls attracted an average of 40 participants each and reached 7 poultry complexes and over 280 flock supervisors. Extension also set up an **HPAI Educational Resources Page** on NC State’s **Poultry Extension** website, which received nearly 1,300 views in 2022. Extension remains in constant contact with the industry via email lists, providing education, HPAI status updates, and press releases, continuously strengthening **Extension’s relationship with industry and helping prevent potential devastation to NC poultry production**.

In Forsyth County, Extension held a webinar for livestock producers and provided **individual consultations** in person and via phone and email, providing education on best practices for forage fertilization and pasture management. A total of 497 livestock producers were reached through these efforts, and 68% of them completed a post-evaluation. Seventy-two percent of participants increased their knowledge of pasture and forage management, and 63% planned to adopt Extension recommended practices. **Helping farmers increase the efficiency of their forage operations so they can increase animal production is part of how we are growing North Carolina.**

As a result of NC State Extension educational programs and technical assistance, **6,975 producers** increased knowledge of pasture/forage management practices, **4,614 producers** increased their knowledge of nutrition and breeding, and **5,033 producers** increased knowledge of strategies for promoting animal health and welfare.

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

By using **value-added marketing channels** such as truckload sales, cattle producers can enjoy significant premiums. In 2022, Rutherford County Cooperative Extension and partners facilitated **truckload lot sales** for over 20 producers, helping them pool their resources to evaluate and process calves. About 1,250 calves were sold at premiums ranging from $100–$200 a head. At an average premium of $150 a head, producers secured added profits of around $187,500 thanks to these sales. In Duplin County, Extension partnered with producers and board members of the previously dissolved Coastal Carolina Cattle Alliance to revive this desperately needed service during a time of rising costs and shrinking profit margins. This revived program helped 9 producers from Duplin and surrounding counties sell 3 truckload lots of cattle (a total of 229 head) via **video auction**, allowing producers to get better value for their animals and strengthen the national food supply by shipping healthy, well-managed stock around the country.

Extension in Rutherford County partnered with a local veterinary clinic to hold a **breeding soundness workshop** for local producers. As a result, 2 bulls were found to be infertile, and the producers saved an estimated $40,000 in lost income due to lack of calving. Extension in Warren County also provided **bull breeding soundness exams**, partnering with the NC State Veterinary School to examine 28 bulls, 4 of which were found to be unsuitable for breeding, preventing an estimated $15,000 in financial losses. In Watauga County, Extension provided **education in disease prevention, nutrition, and bull breeding soundness as well as annual bull soundness exams**. Extension also worked with a local veterinarian to provide **free and reduced-cost vaccines and parasite control treatments** to producers. In 2022, 26 producers had bulls evaluated for breeding soundness, of which 9 were found to be unsuitable for breeding. Producers able to replace inferior bulls save an average of $6,000 in losses per inferior bull by avoiding later born cows or open cows (cows without pregnancies), and the vaccinations and parasite control added an estimated value of $100 to each animal. In Surry County, Extension helped beef producers enhance the effectiveness of natural breeding by delivering targeted **educational programming on the importance of bull selection** and providing **one-on-one selection assistance**. Based on Extension recommendations, 21 performance tested bulls were purchased, securing an estimated value increase of $221 per calf produced. Given that each of these bulls will be mated to an average of 45 cows, producing about 945 calves, the total estimated increased value for the producer is over $200,000.

To help 85 small beef producers enhance the genetics of their herds, Extension in Yancey County partnered with the Yancey County Cattleman's Association (YCCA) to provide **hands-on education in artificial insemination (AI)**. Ten producers learned the entire AI process, and Yancey Extension and YCCA worked together to secure specialized AI equipment. To date, 8 local beef producers have used the shared AI equipment, and several more have plans to begin an AI program. Using AI can generate profit increases of $1,000–$4,000 per producer per year due to higher quality calf production and elimination of the need to purchase and maintain a herd bull. Extension in Surry County delivered numerous **educational and certification programs** to help cattle producers earn more and save more. Based on producer evaluations, county-based research projects, and new marketing plans, purchasing plans, and best management practices adopted, the cumulative financial impact of these programs was over $1.6 million in 2022**. NC State Extension provided cattle producers with technical assistance and training on breeding and other best management practices to increase the profitability of their operations.**

In 2022, Extension continued helping producers develop cost-effective, efficient, and environmentally friendly strategies for **pasture management**. Polk County Extension developed an in-depth 6-week **pasture and forage management course** covering soil health and fertility, pasture ecology, forage variety selection, grazing management, and forage nutrition. The program was held in partnership with the Clemson Extension livestock agent in the area and brought in forage specialists from Clemson and NC State. Thanks to the information and hands-on training provided by this program, 21 farm owners or managers representing approximately 1,350 acres enhanced their forage management abilities. Most participants reported an increase in pasture productivity, with some reporting as much as a 50% increase in forage availability over the previous year. In a year when hay costs were at an all-time high, this increased productivity saved producers up to $500 per 1,000 pounds of animal body weight and up to $10,000 per farm.

Extension helped pork producers keep pace with complex and evolving environmental regulations **for waste management,** by providing assistance with a broad range of tasks, including sludge management, irrigation and litter calibration, record-keeping, manure sampling, general permits, and nutrient management plans. Extension in Bladen and Sampson Counties provided 90 producers with 282 total hours of **continuing education** and helped farms **perform sludge surveys** on 72 lagoons, submit approximately 1,300 lagoon samples to the NCDA, write 5 **litter plans** for 924 acres and over 200,000 pounds of plant available nitrogen, and calibrate 4 equipment systems. Thanks to these efforts, producers saved nearly $20,000 on surveys and calibrations and avoided hefty fines of up to $25,000 per day for waste management violations. Randolph County Extension helped 5 poultry producers representing 2 companies across 4 counties **develop waste plans**, impacting over 600,000 birds, the annual production of 7,000 tons of poultry waste, and hundreds of acres of NC farmland, which were enriched with poultry litter. Duplin County Extension **helped local producers apply for the NCDA&CS COVID Swine and Dairy Program**, supporting 58 farms who lost production contracts and went months without income during the pandemic. By providing phone, email, and one-on-one assistance with the application process, Extension helped pork producers apply for over $2.7 million in assistance covering lost income, lagoon closure costs, and barn renovation costs. Following Extension training and outreach efforts across the state, 2,003 producers increased their knowledge of animal waste management practices, 4,583 animal waste management credits were earned, 192 on-site sludge surveys or equipment calibrations were conducted, and 178 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.**

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

Pandemic induced national meat shortages resulted in increased direct-to-consumer demand for local meat leaving farms and independent processors scrambling to respond. New entrepreneurs rush to open facilities while existing small processors expand, risking return on investment and efficiency challenges especially in a pinched labor market. To ensure that NC citizens enjoy consistent, affordable access to local meats, local processors need assistance tackling the complex problems they face. To address this, the **NC Choices program** has played a significant role in helping producers obtain funding from state and federal sources to more than double the total processing of NC animal products in the past 2 years, despite the challenges of the pandemic.

NC Choices worked with 20 inspected processors, providing peer-to-peer exchanges, in-plant assessment and training, regulatory support, and one-on-one assistance navigating grant and permit application processes. NC Choices also added a new processor training event in partnership with the NC Meat Processor's Association, which included 98 independent processor registrants over 2 days. NC Choices played a significant role in developing educational programming and bringing in industry experts, including some from out of state, to address a variety of topics, including increasing plant capacity; safe, efficient, and equitable workforce development and expansion; and reducing processing costs and defects. Participants gave the training an average of rating of 4.5 out of 5 for effectiveness, and an average 4.5 out of 5 for their intention to apply what they learned to increase production or sales. In addition to this 2-day training, NC Choices leveraged Extension funds to provide 10 processor scholarships to participate in the Meat Processor Academy, a self-paced online course for independent meat processors who want to gain control of their efficiency, productivity, and profitability. The Meat Processor Academy was

developed by the Niche Processor Assistance Network, an Extension community of practice groups working with independent processors. The academy includes 14 hours of training spanning business planning, lean manufacturing techniques, facilities management, financial management, human resources, and marketing strategies.

NC Choices also secured funding to expand MeatSuite.com, a direct-to-consumer bulk buying platform that helps farmers expand their reach and connect with consumers. Buying locally strengthens regional economies, supports family farms, and provides fresh foods for consumers. NC Choices secured USDA funding for this expansion, which included new resources and training features on the site, such as a meat price calculator and text notifications for customer product questions. NC Choices also launched a series of trainings across the state, working with the NC Cattlemen's Association to bring MeatSuite.com to their annual conference and train their audience in the use of this digital resource. The site now has over 250 farmer profiles and has received 46,476 consumer site visits to date, 7% of whom click through to make purchases. **Extension partners with NC Choices to deliver education, technical assistance, networking opportunities, and direct-to-consumer engagement methods that benefit the public by promoting the growth, sustainability, and accessibility of NC's local, niche, and pasture-based meat supply chains.**

Extension empowered small poultry growers with technology resources, reducing processing and transportation costs. Union County Extension used grant funds to purchase a mobile poultry processing unit (MPU) to be used by local small farmers and compensate for the current total lack of poultry processing plants in NC. The MPU was advertised to producers, and Extension gathered feedback on their needs to purchase additional equipment and enable processing of turkeys as well. Eleven farms rented the MPU a total of 16 times in 2022, processing 926 birds, including broilers and turkeys. Producers were also provided with hands-on demonstrations of the MPU technology and presented with best management practices. Many renters raised broilers for the first time because of this unit and plan to raise more birds in the future. Prior to being given access to this MPU, Union County poultry producers had to travel 4 hours round trip to the closest facility in King's Tree, SC at an average cost of $224 per trip. Harnett County, Extension continued using a mobile poultry MPU to deliver training to local small-scale producers. In 2022, 35 producers used the MPU, each processing an average of 75 birds across a 3-day use period. This equipment saved small producers an estimated $13,375 in processing costs, enabling them to strengthen their operations and explore expanding into other areas of animal husbandry, including hogs, sheep, goats, and cattle.

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 2022 to facilitate the use and transfer of new research-based knowledge:

- Animal Ag Agent Training BQA Chuteside and Low stress handling
- Animal Ag Agent Training Dairy 101
- Animal Ag Agent Training Developing a Forage System
- Animal Ag Agent Training Precision Applications in Swine
- Animal Ag Agent Training Small Ruminant Facility/Nutrition/Grazing
- Aquaculture - Update on NC Industry and Opportunities
- Carbon Credits for Livestock Producers
- Demonstration of Real-time Assessment of Forage Nutritive Value

- Discover NC Dairy 360
- Pet Food Extension Agent Training
- Sheep Shearing Workshop
- Swine Industry Energy and Environment

The following **Factsheets and Peer Reviewed Extension Publications** were developed by Extension Specialists for dissemination of research-based information to Extension agents, growers, and other stakeholders.

2023 North Carolina Agricultural Chemicals Manual (AG 1)

- IV. Fertilizer Use
- IX. Animal Disease Control

Biochar Production through Slow Pyrolysis of Animal Manure (AG 919-06)

How Does Nitrogen Move Through a Swine Farm with a Lagoon-Sprayfield System? (AG 927)

Pasture Grazing Heights for Rotational Stocking (AG 939)

Best Management Practices for Agricultural Nutrients (AG 439-20)

Raising Prices on Meat, a Pep Talk (LF 019)

Extension specialists contributed to solving regional and national issues through **multi-state collaborative Extension efforts**. Some multi-state programs NC State Extension participated in included:

- NC1173. Sustainable Solutions to Problems Affecting Bee Health, which involves both research and extension collaborative projects.
- NC1211. Precision Management of Animals for Improved Care, Health, and Welfare of Livestock and Poultry. This group deploys a combination of engineering, animal science, and data science for the development, validation, and application of data, software, and controls to create usable information for assessments and improvements in livestock production and management. The 46 members of this group represent 21 universities, 5 companies, and 4 countries, further expanding collaboration network and program impact.
- NE1492. Multi-State Project. Enhancing Poultry Production Systems through Emerging Technologies and Husbandry Practices
- NE1941 Environmental Impacts of Equine Operations.
- NRSP8 National Animal Genome Program. The goal of this program is to sequence and annotate the genomes of all agriculturally relevant animals in the US (national consortium).

- NRSP9. National Animal Nutrition Program. Poultry modeling representative on the modelling subcommittee and Modelling committee - animal workshop.

- S1074: Future Challenges in Animal Production Systems: Seeking Solutions through Focused Facilitation

- S1069. Research and Extension for Unmanned Aircraft Systems (UAS). Aquaculture representative and tied in with work on autonomous vehicles in oyster culture (NSF/USDA funding) in parallel with multistate work.

- MeatSuite.com collaboration with Cornell University

- Niche Meat Processor Assistance Network, part of Extension Foundation Community of Practice

- Development of joint programming and fundraising through meatsummits.com with seven Universities and two partner organizations.

- Southern Regional 4-H Horse Program Committee

- Southern Regional 4-H Horse Championships Committee

- Eastern National 4-H Horse Roundup Committee

- American Dairy Science Association Extension Committee

- National Academies Sciences Engineering, and Medicine writing committee for Nutritional Requirements of Poultry.

- Supported NRCS agents in Vermont and North Carolina developing grazing plans for pasture-based pig production systems.

- Livestock and Poultry Environmental Learning Community (LPELC). This group oversees a monthly webinar series focused around environmental aspects of animal production and a biannual conference (Waste to Worth) which brings applied researchers and practitioners engaged in waste management and valorization in the animal industry sector.

- Traveled to Iowa, Indiana, Pennsylvania, and Kentucky to aid farming in dealing with HPAI outbreaks on behalf of the USDA.

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.

As a result of NC State Extension educational programs and technical assistance, 6,975 producers increased knowledge of pasture/forage management practices, 4,614 producers increased their knowledge of nutrition and breeding, and 5,033 producers increased knowledge of strategies for promoting animal health and welfare.

delete

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

x

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.

x

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

x

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

x

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.

x

Developing New and Emerging Horticultural Crops and Improving Organic and Sustainable Vegetable Production

Project Director
Jeanine Davis
Organization
North Carolina State University
Accession Number
1023645

Annual Result: Developing New and Emerging Horticultural Crops and Improving Organic and Sustainable Vegetable Production

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

To help keep agriculture profitable in North Carolina, it is necessary to explore production of new high-value crops, develop improved varieties, and test alternative production methods. The objective of this program is to increase diversity, sustainability, and profitability of agriculture in North Carolina and the Southeastern US through development of medicinal herbs, new horticultural crops, and organic and sustainable vegetable production systems.

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 been engaged in five major projects during this report period:

- Breeding hops for the Southeastern United States: A strong local food movement and large number of craft breweries created a demand for locally grown hops. Most commercial hop varieties, however, were bred for production in the Pacific Northwest. Hops are sensitive to day length, and these varieties produce very low yields in south (days are too short). We have been breeding hops specifically for southern latitudes, and the warmer and wetter conditions often found there. This past year we tested two advanced breeding lines in several on-farm trials, collected yield and quality data from multiple new breeding lines in research station studies, and worked with eight breweries to run sample brews with hops from the new breeding lines.

- Creating production systems for forest grown botanicals: Forest farming is a way to generate income by growing desired plants under the forest canopy. The rising demand for medicinal herbs that are traditionally wild-harvested is putting increased pressure on native populations, presenting an opportunity for forest landowners to cultivate these plants in their woods. We have been engaged in projects on germplasm collection, propagation, planting methods, and farmer education on some of the more popular plants, including ginseng, goldenseal, false unicorn, and black cohosh. During the past year, a major emphasis was placed on developing efficient and reliable propagation methods and working with nurseries to produce planting stock for this growing industry.

- Evaluating hemp as a profitable, high-value crop for western North Carolina: Many farmers across North Carolina initially grew hemp for production of biomass (the whole plant) to be extracted for CBD. As in many other states, the CBD market was quickly saturated, prices fell dramatically, and interest in the crop quickly waned. Many large-scale farms, especially in the far eastern part of the state, are now experimenting with fiber hemp. There are, however, a growing number of small-scale hemp growers, especially in western North Carolina, growing floral hemp in vertically integrated businesses or for specialty manufacturers to produce smokable bud, and value-added products such as tinctures, salves, gummies, and lotions. To help our farmers produce high yields of quality floral hemp, in 2022 we have been completed a series of variety trials, planting date and harvest date studies,, and testing of several drying strategies.

- Creating an Eastern broccoli industry: We have been engaged in a long running, SCRI funded project on broccoli. This project, led by Cornell University, now extends from Maine to Florida. Most broccoli is grown in California and Arizona and shipped across the country. It would be more economical and fuel efficient to produce broccoli for Eastern markets in the Eastern US. Unfortunately, available commercial varieties were not well suited to the wetter environments of the Eastern US. In partnership with private breeders, our team has been developing and testing new varieties and breeding lines in an effort to create a year round supply of broccoli grown exclusively in the Eastern US. Our role has been to evaluate broccoli varieties and breeding lines for summer production in the mountains of western North Carolina. This study was completed in 2022.

- Developing tomato varieties for organic production: Commercial tomato production in the Eastern US relies on conventional fungicides, insecticides, and fertilizers for high yields of marketable fruit. There is a strong demand for organic tomatoes, but producing them in the Southern US where disease and insect pressure is high, is quite challenging. We have been engaged in a multi-state, OREI funded project and an NC State University led project to breed and test new selections of tomatoes grown under certified organic conditions. These studies were conducted in the organic unit on a research station and on local farms.

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

- Breeding hops: This project has two target audiences. The first one is North Carolina hop growers and farmers who want to grow hops. They are interested in the progress of this research because the yields they get from current varieties do not satisfy the demand for locally grown hops and are not economically viable. This past year, two established NC hop farmers grew two of our advanced breeding lines on their farms. The growers are optimistic that these new breeding lines will help make their operations more profitable and support expansion of their hop yards. The second target audience is local craft breweries. Brewers have been engaged in this project for years and brew sample beers with the new hops to ensure the new lines have the brewing qualities they desire. They have been very pleased with the results so far.

- Forest farming botanicals: This project also has two target audiences. The first one is composed of forest farmers and landowners interested in becoming forest farmers. Our research and extension activities have supported expanded plantings across the region. The second audience is composed of the buyers of these plants. For many years, herbal product manufacturers have expressed interest in buying cultivated woodland botanicals, but there were not enough growers to supply even a fraction of their needs. This is changing and some of the buyers are making special efforts to assist with development of the farmer base. We have also put an emphasis on helping nurseries produce planting stock for this industry.

- Hemp: The target audience for our hemp projects are existing and potential hemp growers. Hemp is a new crop and all aspects of production need to be studied and refined. Farmer input on the hemp research projects is high, and we see adoption of new varieties and practices very quickly. Interest in floral hemp and fiber hemp is high.

- Broccoli: The target audiences for the broccoli research are vegetable farmers and wholesale produce buyers. There is a growing interest in producing broccoli in western North Carolina, and some farmers are successfully doing so. Market demand is also on the rise. The most limiting factor to the expansion of this industry right now appears to be cooling capacity; to maintain quality; broccoli must be cooled very soon after harvest.

- Organic tomato varieties: The target audience is organic vegetable farmers of all scales of operation. Because of the use of on-farm tests, farmers are exposed to these new lines very early and they report satisfaction in the field and in the marketplace.

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

The public wants to buy affordable, high quality, locally grown products. These research projects on hops, hemp, woodland herbs, broccoli, and organic tomatoes are all designed to help provide those products to the consumer, directly and through restaurants and breweries. At the same time, local market demand benefits farmers by reducing shipping and storage costs and building local brand identity. Financially stable farms benefit our community by providing green space and helping maintain the natural beauty of an area that is highly dependent on tourism.

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.

All of these projects have strong extension (outreach) components to them. Grower education and extension agent training are provided through conferences and workshops, both virtual and in-person. The forest farming project has a mentor training component to it that we call the Woodland Stewards. Outreach through social media, particularly Facebook, has been strong.

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.

DELIVERED INSIGHTS AND NEW VARIETIES TO ENHANCE SPECIALTY CROP PRODUCTION: To help keep agriculture profitable in NC, growers need improved varieties and assistance producing new high-value crops. To strengthen the diversity, sustainability, and profitability of agriculture in NC and throughout the Southeastern US, NC State researchers are conducting research and field trials and providing education to ensure growers are prepared to take advantage of growing consumer demand for specialty crops. Milestones to date include breeding and testing new hop varieties specialized for production in the warmer, wetter conditions often found in southern latitudes; creating efficient, reliable production systems for forest botanicals and educating growers to accommodate a growing consumer interest in medicinal herbs; and completing variety trials and testing drying strategies to help farmers produce high yields of quality floral hemp. NC State researchers have also collaborated with Cornell University and private breeders to develop and test new broccoli breeding lines in an effort to create a year-round supply of this valuable, in-demand crop grown exclusively in the Eastern US. In addition, NC State is collaborating on a national project to breed and test new tomato varieties for organic production. The results of this research are shared with growers and the general public through conferences, workshops, and social media outreach.

delete

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

x

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.

x

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

x

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

x

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.

x

Horticulture Plant Systems

Project Director
Meredith Weinstein
Organization
North Carolina State University
Accession Number
7000167

Annual Result: Horticulture Plant Systems

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

Fruit and vegetable production plays a key role in North Carolina'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. In addition, North

Carolina has a diverse turfgrass industry totaling 2,007,100 acres. Turfgrasses are maintained at single family dwellings, roadsides, parks, commercial properties, churches, golf courses, schools, airports, institutions, and cemeteries.

The world's population is expected to 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, pressure is 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. 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. In addition, home gardeners and landscape professionals need to learn and adopt practices that provide sustainable landscapes and conserve and protect environmental health. 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.

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 specialists used applied research, diagnostic testing, and variety performance evaluations to develop innovative products, technology, and research-based horticulture best management practices (BMPs) that support sustainable horticultural production. Extension specialists led applied research efforts to reduce plant diseases and pests through improved crop management, variety selection, and pesticide management. Extension specialists and Agents delivered information on these innovations and practices and promoted the adoption of BMPs through Extension publications, websites, meetings, workshops, seminars/webinars, videos, newsletters, clinics, consultations, community and demonstration gardens, certification programs, and public outreach efforts to support commercial growers, nursery professionals, resident gardeners, and landscape professionals.

- NC State Extension specialists disseminated new horticulture information and best practices through the publication of around 125 ***Extension publications*** to educate Extension Agents, producers, and members of industry.

- NC State Extension specialists maintained 20 horticulture **websites** that were viewed approximately 400,000 times in 2022 to disseminate up-to-date research-based information and best practices.

- 40,000 individuals attended training offered by Extension specialists, and 50,000 individuals attended consumer horticulture-related **training** provided by Extension Agents.

- 3,515 Master Gardener **volunteers** donated nearly 200,000 hours valued at over $5.7 million, reaching over 187,000 NC residents.

In 2022, Extension expanded and enhanced web-based and on-demand education resources and tools, benefitting growers and the public at large. Extension in Chatham County contributed over 45 new articles to the **Growing Small Farms website**. Since its establishment in 2001, this site has grown to over 500 pages and over 400 posts promoting agricultural literacy and highlighting local farms and farmer's markets. With topics ranging from pollinator gardening, to farmer education, to farm and garden tours, this site attracted nearly 240,000 visits in 2022, and its content was widely shared on social media.

In 2022, Extension continued adapting to the post-pandemic world and providing **media resources** to support rapidly growing consumer interest in horticulture. Extension in Guilford County cultivated a new partnership with local news channel WGHP Fox 8, delivering 8 weekly fall gardening episodes, each of which attracted an average of 32,000 viewers, with a total viewership of 256,000. In Henderson County, Extension worked with WTZQ Radio to produce a series of live weekly home gardening segments, eventually leading to the production of the Gardening in the Mountains Radio show and podcast that now airs weekly on Saturday mornings to an audience of as many as 10,000. This show has aired nearly 100 episodes to date, providing people with seasonal gardening tips. Edgecombe County Extension also made strides in radio outreach, promoting Extension and providing 4 to 5 themed horticulture broadcasts monthly, with topics spanning beekeeping, garden management, seasonal plant selection, and soil management. This local radio show airs on 2 stations in Rocky Mount and Sanford, reaching an estimated 20,000 to 25,000 people per day. **NC State Extension empowers individuals to make decisions by providing research-based information through media outreach.**

The **NC Extension Gardener Online Plant ID courses**, offered in partnership with Longwood Gardens, encourage students to explore the world around them and gain a better understanding of plant identification. Students study 50 plants in each course and gain skills in finding and using different apps and websites, such as the Extension Gardener Plant Toolbox, a tool that unifies information from plant databases around the world. This tool helps people select plants that will thrive in their yards while providing beauty and functional landscaping benefits. In 2022, Extension offered a basic botany course as well as 4 different 6-week plant identification classes, each focusing on different groups of plants. Of the 50 students who completed course evaluations in 2022, 87% reported a better understanding of plants, 63% reported more joy and confidence in gardening, and 54% felt better prepared to work with plants professionally or on a volunteer basis. A number of students have used these courses to jumpstart a transition to a green industry career or a graduate program, and many students report that these courses have helped them feel more connected to the natural world. Cooperative Extension also partners with the North Carolina Botanical Gardens to offer a 6-week online non-credit class in Therapeutic Horticulture. Students learn to design therapeutic horticulture treatments and programs for diverse sites and participant populations. Traditionally, therapeutic horticulture training has been face-to-face and expensive, but this online, affordable course makes this training available to a wider population. **NC State Extension works with local partners to bring the many benefits of horticulture to an increasingly broad audience.**

To ensure growers benefit from NC State's blueberry breeding program, Cooperative Extension hosts annual field days for growers. Although this event was previously impacted by COVID-19 restrictions, in 2022, an in-person field day was hosted in conjunction with the New Hanover County Blueberry Festival, which attracted 200 attendees. These stakeholders were informed of the current status of the breeding program, including new cultivars that have been tailored to meet the needs of NC blueberry growers. **NC State Extension transfers the latest practices to growers at workshops, seminars, and meetings.**

As a result of NC State Extension programs, over **425,000 participants** gained knowledge of landscape, turf, and garden best management practices, including pest and soil management. Over **100,000 participants** use Extension-recommended best management practices in landscapes, turf, and gardens; and nearly **55,000 participants** selected appropriate landscape plants after participating in Extension consumer horticulture programs.

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

Early spring frost and freezes are a common threat to fruit producers along the Eastern Seaboard. Small acreage growers are particularly vulnerable to weather-based threats. To provide timely freeze and frost prediction information for growers and Extension Agents, Extension specialists continued a popular **weather advisory program** that distributes crucial information through the NC State Extension strawberry and grape web portals, reaching an audience that stretches from the Mid-Atlantic to the Southeast. This program collaborates with AWIS weather services to obtain exclusive temperature maps, weather discussions, and forecast tables. This weather advisory program is currently attracting over 10,000 viewers per month to the NC State Extension strawberry web portal and 2,000 viewers per month to the grape web portal. Extension also educates growers on freeze and frost protection for strawberries and grapes through publications and webinars. Given that late spring frosts frequently lead to losses of 10–30% in strawberry and up to 100% in grape crops, these timely updates help growers avoid devastating crop and profit losses. **NC State Extension provided solution-driven research and technology to empower growers to make better-informed decisions.**

Grapevine viruses can lead to substantial reductions in yield and fruit quality in wine grapes and are among the greatest threats to the grape and wine industry worldwide. Grapevine virus symptoms are often non-specific and can be easily confused with the symptoms of other problems, such as nutrient deficiencies and physical damage. To address this problem, Extension partnered with NC State research programs, Foundation Plant Services at UC Davis, and the USDA-ARS in Davis, CA to **assess the distribution and severity of common grapevine viruses in NC** between 2018 and 2020. This joint effort also led to new identification and sampling guidelines and the development of a new virus testing program that dramatically reduces costs to growers (from $800 to $1,000 per sample to about $150). As a result of this program, growers are now more aware of the most common grapevine viruses in NC vineyards, and they can more easily identify and treat grapevine viruses in their vineyards.

Grapevine training and pruning is the most invasive and critical cultural management practice in a vineyard. Poor pruning can reduce longevity, yield, and fruit quality while making crops more vulnerable to disease. Since 2020, Extension has been partnering with an Italian pruning specialist to offer virtual **pruning workshops**, bringing internationally recognized knowledge to NC growers. These workshops include 4 in-depth classes (each 3 hours long) in which real-world examples of pruning are discussed directly with a grower and an agent. These workshops are offered annually to growers in NC, GA, and VA, with growers reporting thousands of dollars of savings in maintenance and labor costs thanks to skills learned in the workshops. These workshops ultimately support a mindset shift in growers and agents, encouraging them to understand how

pruning affects long-term vineyard longevity, rather than only focusing on short-term yield. **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.**

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. Cucurbit downy mildew is a devastating disease in cucurbit crops and the number one threat to production, especially in cucumber. This disease must 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. NC State Extension specialists work closely with cucurbit growers, cucurbit packers, Extension agents, crop consultants, seed companies, and chemical companies to improve management of cucurbit downy mildew, resulting 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 **2 commercial pickling cucumber varieties** with resistance through collaborations with seed companies. Extension also serves as a state collaborator for the **Cucurbit Downy Mildew IPM PIPE national alert system** and hosts **sentinel plots** on a yearly basis for pathogen monitoring. Extension efforts save growers approximately 4–6 fungicide sprays per year. Because fungicide sprays can be about $30–$50 per acre, per application, per product depending on the product, these efforts would translate into $2.5 to $6 million in annual savings for NC cucurbit growers alone.

The oomycete pathogen Phytophthora capsici can cause root, crown, and fruit rot in cucurbit crops. 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. capsica. 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 despite having excellent practices as far as cultural options and fungicide programs. Better understanding of what was causing these extreme losses was needed. After visiting with affected growers and Extension agents, Extension suspected surface water used for irrigation was infested with P. capsici. Extension took water samples and determined that this was correct, then worked closely with each grower to **develop management strategies** compatible with their situation. Extension recommendations reduced fruit losses from 80% to 20% for 2 of the largest watermelon and squash growers in the state. In the 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.

Continuing education for landscape professionals is vital to improving sustainability and reducing environmental impacts. In 2022, Cooperative Extension provided workshops, seminars, and professional talks to over 5,500 turfgrass managers on diverse topics, including management of warm and cool season turfgrasses, integrated pest management, pesticide and nutrient training, classroom training for turf and ornamental pesticide licenses, turf worker safety, and establishing turf for sediment and erosion control. All participants indicated that the knowledge provided would help them be more efficient and environmentally conscious in their turf pesticide and nutrient programs, 90% greatly increased their knowledge in pesticide application BMPs, 90% reported intention to use integrated pest management strategies, and 80% reported that they will change at least one management practice based on the education presented by Extension. **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 2022, Extension's Master Gardener program (EMG) continued to provide exceptional horticultural education to the general public. Statewide,187,070 residents benefitted from the program's demonstrations, community gardens, workshops, and personalized consultations. Master Gardeners reported 192,346 service hours from 3,515 volunteers for the year, valued at an estimated $5,760,763. In 2022, Extension Master Gardener Volunteers (EMGV) used demonstration gardens, plant clinics and sales, and a variety of other outreach methods to engage with consumers. These efforts contributed resources to local food systems while empowering consumers to grow their own food, care for the environment, and develop a deeper understanding of a broad range of topics, including pollinator health, disease and pest management, plant identification, and stormwater management.

EMGV in Brunswick County hosted an open house at the Brunswick County Botanical Demonstration Garden, showcasing 15 vignette gardens and providing education on soil sampling, stormwater management, and the unique aspects of each garden. Around 200 visitors attended and received one-on-one assistance from volunteers and staff. EMGV interns also cataloged and QR labeled over 660 plants, ensuring that visitors to the garden could easily access information about each plant's characteristics and cultivation needs. At a demonstration garden in Vance County, EMGV partnered with the Extension horticulture agent to implement a comprehensive pollinator conservation education program, drawing attention to pollinator support plants and insecticide-free garden management and delivering an informational bulletin board, staffed information tables, radio segments, newsletter articles, garden tours, webinars, and more. These efforts reached an estimated 200 direct educational contacts and hundreds of indirect contacts through media outreach. Post-event surveys routinely indicate that these efforts inspire gardeners to reduce pesticide use and increase the use of native plants.

EMGV mobile plant clinics in Johnston County were particularly impactful in 2022. EMGV partnered with local businesses to hold 11 mobile plant clinics, offering research-based advice on growing food, landscaping, lawn maintenance, plant choices, integrated pest management, disease management, and proper use of fertilizers and pesticides. Five hundred and twelve people received advice at an estimated total value of $25,600. These efforts also helped secure 1,057 new subscribers (a 73% increase) to EMGV's Gardener's Dirt Newsletter. EMGV in Johnston County also helped provide 140 visitors with gardening classes and workshops at local community gardens, producing 15,000 pounds (an estimated $28,350 value) of fresh food for local soup kitchens and providing an estimated value of $53,350 in gardening advice to an additional 1,067 community members via calls, emails, and walk-ins.

In 2022, EMGV plant sales provided opportunities to fundraise while delivering diverse educational opportunities to community members. Orange County EMGV conducted its first ever independent education and plant sale, attracting an estimated 750 to 1,000 participants who enjoyed 14 educational booths and activities and provided glowing feedback. In Pender County, EMGV held a plant sale that attracted around 700 community members and raised $8,000 for outreach programs.

EMGV in Guilford County developed a series of educational programs called Grow With Us, offering in-person and Zoom-based classes as well as multiple online resources. Grow with Us served more than 1,538 people in 2022, with many participants attending more than one program and indicating that they shared what they learned with family, friends, and gardening groups.

To address growing consumer concerns over inflation and supply chain issues, Extension has empowered community members to grow their own food by distributing seeds. In Moore County, Extension Master Gardener Volunteers partnered with a local library to create a seed library, allowing gardeners to take free seed and bring saved seed back to create sustainability. With seed donated by a Master Gardener Volunteer, Extension established the seed library and created accompanying educational materials as well as a seed saving program. Between April and December of 2022, 247 people took over 1,000 packets of seeds from the library. Four local businesses have since donated to this cause. In Forsyth County, Extension's Community Gardening Program worked with Extension Master Gardener Volunteers to distribute seeds to 28 gardens across the country. At the 9 gardens reporting participation in this program, 114 people grew food at home, harvesting over 482 pounds of produce for household use and donating an additional 615 pounds to a local food pantry.

Master Gardener Volunteers also partnered with Habitat for Humanity in 2022, providing materials, homeowner education, and installation services to ensure that 6 homes had beautiful, sustainable, and resilient landscaping with native plants. Master Gardener Volunteers also held a plant sale fundraiser and "Ask an EMG" event at the Habitat for Humanity location in Southport, raising $1,000 that went directly to Habitat for Humanity. **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.**

To help strengthen local bee populations and educate the public about how to support these critical pollinators, Cooperative Extension published a comprehensive, **peer-reviewed Extension guide** "How to Manage a Successful Bee Hotel." This document went online in July 2022 and received 1,325 hits by the end of the year. It also resulted in a presentation at the 2022 Extension Master Gardener College to provide "train the trainer" guidance in building and managing bee habitats. **By growing public awareness of the importance of pollinators and educating specialists and consumers in how to help them be at home in human-dominated habitats, Extension is building a more sustainable future.**

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 2022 to facilitate the use and transfer of new research-based knowledge:

A Survey of Greenhouse Diseases in NC: Identification and Management

Accessibility & Inclusiveness with the Ability Garden

Basic Tree Risk Assessment & Structural Pruning

Boosting Roots, Up and Down Strategies of Utilizing PGRs

Certified Plant Professional Plant Identification Training

Coleus Diagnostics and Production

Eastern NC Nursery Conference: Red-headed Flea Beetle Research

Flatheaded Appletree Borers Best Management Practices to Prevent

Grapevine Cane Pruning

Grapevine Pruning and Shoot Thinning

Grapevine Pruning Basics

Grapevine Spur Pruning Workshop

Growing a Tropical Like Native Fruit - Pawpaw

Herbicide Injury Symptoms, Diagnosis & Response

Integrated Pest Management of European Pepper Moth

Is Sesame Our Next Big Oilseed Crop

Keep Christmas Trees Fresh: How to Answer Holiday Consumer Calls

Managing Hard to Control Weeds (Moss, Liverwort, and Nostoc)

Morphology and Identification of Grasses, Sedges, and Rushes

Muscadine Pruning Workshop

Must Have Greenhouse Gadgets and Apps

Online Master Gardener Training

Ornamental Horticulture

Ornamental Nursery Production Tour

Pests and Diseases of Nursery-Grown Ornamental Plants

Plant Problem Diagnostics

Rethinking the Invasive Conundrum

Spotted Lanternfly in PA Nurseries

Strawberry Production

Tomato Production

Turfgrass Disease Diagnosis & Management

Turfgrass Management and Fertility

Warm Season Turf Maintenance - Diagnosing Warm Season Turf Pests

What To Do If You Suspect Herbicide Contamination?

The following **Factsheets and Peer Reviewed Extension Publications** were developed by Extension specialists for the dissemination of research-based information to Extension agents, growers, and other stakeholders.

2023 North Carolina Agricultural Chemicals Manual

2022 Southeastern US Vegetable Crop Handbook

2022 Integrated Orchard Management Guide for Commercial Apples in the Southeast

North Carolina Extension Gardener Handbook

2022 Sod Producers' Report for North Carolina

Preparing Nursery Plants for Winter

Irrigation Water Quality Problems

Biopesticides for Disease Management in Vegetable Crops

Tall Fescue and Kentucky Bluegrass Home Lawn Calendar

Tall Fescue, Hard (Fine) Fescue, and Kentucky Bluegrass Home Lawn Calendar

Prevention and Management of Soilborne Diseases of Ornamental Plants and Vegetables in the Greenhouse

Water Quality and Sprayer and Spreader Calibration

Water Quality and Professional Lawn Care

Water Quality and Commercial Lawn Care

Water Quality and Professional Turfgrass Managers

Screening Sesame for Resistance to Multiple Root-Knot Nematode Species

Fusarium Wilt of Blackberry

Exobasidium leaf and fruit spot of blueberry

Gray Leaf Spot of Tomato

Fresh-Market Muscadines: A 2019 survey to gather insights into important issues for growers

Strawberries: Late Planting and the Use of Floating Row Covers

European Pepper Moth in Nurseries and Greenhouses

Cream Leaf Blight in Turf

Management Guide for Sour Rot in North Carolina

Pine Bark Beetles

Black Rot of Brassicas

Oystershell Scale

Annual Ryegrass

Bahiagrass

Bermudagrass

Buffalograss

Carpetgrass

Centipedegrass

Creeping Bentgrass

Fine Fescue

Kentucky Bluegrass

Perennial Ryegrass

Rough Bluegrass

St. Augustinegrass

Tall Fescue

Zoysiagrass

Extension specialists contributed to solving regional and national issues through **multi-state collaborative Extension efforts**. Some multi-state programs NC State Extension participated in included:

- Southern Region Strawberry IPM Working Group
- Southern Region Veggie Crop Working Group
- Southern Region Steering Committee small fruit industries
- Southeastern Vegetable Extension Workers Group 14 institutions edit the Southeastern Vegetable Production Handbook, organize multi-state variety trials, maintain listserv, discuss vegetable production issues
- Great Lakes Hops Working Group Annual meetings, monthly discussions
- NCERA224. Extension and IPM for ornamental plants
- S1073 IPM and Biocontrol of pests on ornamental plants
- Collaboration with a team of 16 scientists across 15 universities to limit the impact of annual bluegrass; University of Georgia, Auburn University, the University of Tennessee and Clemson University to investigate pesticide environmental fate
- National Viticulture and Enology Extension Leadership Committee
- NCCC 212 Small fruits and viticulture
- Multi-state project focused on research and extension with the dollar spot pathogen.

- Turf multistate activities - University of Florida evaluation of new Bahiagrass varieties; Purdue University Bermudagrass Mite regional topics in warm and cool season grasses; Clemson University evaluation of Nematode and Take-all-root rot samples in warm season grasses; Virginia Tech University herbicide evaluation for warm season turf in the transition zone; University of Tennessee collaboration of bermudagrass varieties in the transition zone

- Regional Approach to Cucurbit Downy Mildew Preventiont 29 states monitor downy mildew on cucurbit outbreaks, coordinate state activities, identify management solutions, and educate growers on disease management and identification

- Management of Endemic and Emerging Bacterial Diseases of Capsicum 4 universities and USDA-ARS Identify bacterial pathogens on pepper, evaluate alternative spray programs to manage diseases, identify novel sources of resistance, educate growers on management solutions

- Caneberry and Apple disease content for MyIPM App

- PathMap Fungicide resistance profile map in fruit crops app development: NCSU, USDA-ARS, PSU, MSU, Colorado State University, Cornell

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 NC State Extension programs, over 425,000 participants gained knowledge of landscape, turf, and garden best management practices, including pest and soil management. Over 100,000 participants use Extension-recommended best management practices in landscapes, turf, and gardens; and nearly 55,000 participants selected appropriate landscape plants after participating in Extension consumer horticulture programs. Because 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.

delete

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

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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.

x

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

x

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

x

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.

x

Multidisciplinary approach to improving gut health and feed efficiency in ruminants

Project Director
Uchenna Anele
Organization
North Carolina Agricultural and Technical State University
Accession Number
1023327

Multidisciplinary approach to improving gut health and feed efficiency in ruminants

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

The use of plant nutraceuticals in livestock production continues to get traction despite the mixed results (short-term effect and inconsistent effect across-the-board) associated with their use. The project will evaluate different product blends from nine plant nutraceuticals (including 17 essential oils) to improve feed efficiency, reduce greenhouse gas emissions and improve gut health of ruminants. This will help reduce the amount of nutrients excreted from ruminants thus protecting environmental and natural resources. The project will also evaluate the effects of the product blends on rumen microbiome dynamics and metabolomics through big data analytics.

We hypothesize that combining different plant nutraceuticals will enable the team to develop a superior product blend that will improve feed efficiency and gut health in ruminants. This will be addressed by following these specific objectives:

1) Extract and estimate the bioactive components of 9 different plant nutraceuticals;

2) Use the in vitro batch culture technique to screen different combinations of the nutraceuticals to improve feed efficiency;

3) Use the rumen stimulating technique (RUSITEC) to further evaluate the different product blends;

4) Evaluate the effects of three final product blends on feed intake, nutrient digestibility, rumen fermentation, and milk yield and composition of dairy cows;

5) Evaluate their effects on the microbiome, metabolites and cytokines; and

6) Develop a final product blend that will consistently improve feed efficiency and gut health in ruminants.

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 the second year of the project, my lab was able to identify 3 essential oil blends/products (we formulated and evaluated 9 blends in the first year) that we evaluated and they are currently being evaluated into the third year. We have completed the in vitro batch culture of these blends and compared them with their individual essential oils. We have also included the evaluation of onion peel. For this new substrate, we have done some batch culture studies and an infusion study with 6 canulated beef cows. For the current reporting period, we have accomplished objectives 1, 2, and 5 (microbiome and metabolome) of the project.

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

The project is still on-going but some of the results were shared with socially disadvantaged and limited resource farmers at a national conference on next-generation sustainable technologies for small-scale producers held at North Carolina A&T State University. Future results will also be shared at other conferences and workshops, such as Small Farms Field Day and Small Farms Week. We will also develop one or two fact sheets that will be disseminated across the state as a means for agents to provide brief communications to ruminant producers.

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

Our results have shown a significant reduction in greenhouse gas emissions which is consistent with our overall goal to improve feed efficiency in ruminants. The project will provide practical solutions to improving feed efficiency in ruminants. Feed efficiency is a key criterion to improve the economic as well as environmental sustainability of any ruminant enterprise. Additionally, improving feed efficiency will help reduce energy losses as methane, and nitrogen as ammonia, which typically reduce animal performance and contribute to greenhouse gas emissions into the environment. Improving the efficiency of feed utilization, therefore, can have dramatic effects on profitability and sustainability. The project will provide information on incorporation of nutraceuticals for ration formulations.

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.

There is no major change in the proposed approach. I have had facility issues (nothing major and have worked with the facility manager to rectify things). Another challenge is lab supplies that are on back order (from few weeks to months). I have tried to look for alternatives, but this may not be possible for certain items. One of the MSc. student presented her results at the Association of 1890 Research Directors Research Symposium and 3 undergraduate students also presented 3 posters at the North Carolina A&T Undergraduate Research Symposium. We have also published 1 peer-reviewed article from the project and currently working on 2 other manuscripts.

The results of the in vitro batch culture studies are consistent with our hypothesis. We noted significant differences in dry matter disappearance, abatement of greenhouse gas emissions, improved volatile fatty acid concentrations. We plan to expand to more whole animal studies in the third year while continuing with some in vitro and RUSITEC studies.

Population Biology and Evolutionary History of Phytophthora species on Solanaceous Crops

Project Director
Jean Ristaino
Organization
North Carolina State University
Accession Number
1023961

Annual Result: Population Biology and Evolutionary History of Phytophthora species on Solanaceous Crops

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

The genus *Phytophthora* contains many destructive plant pathogens with great impact on agriculture. *Phytophthora* species represent a significant and emerging biosecurity threat due to increases in plant movement via international trade. There is also the potential for the emergence of new *Phytophthora* species or genotypes within a given species through evolutionary change. There is a need to develop better detection and surveillance technologies to mitigate threats and better tools to understand evolution of new species.

Phytophthora infestans is one of the most serious threats; it was the first species in the genus described and left a path of devastation on potato in its wake in the US, Ireland and Europe in the 19th century. New strains of the pathogen have migrated over great distances from South America and more recently from Mexico to cause significant losses for growers worldwide

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.

Objective 1. Develop, validate and deploy novel microneedle patch (MN) based Loop-mediated isothermal amplification (LAMP) assays and Volatile Organic Compound (VOC) sensors for detection of *Phytophthora infestans* and other emerging *Phytophthora* species.

We have developed LAMP assays deployed on smart phones and a phone APP for rapid in field detection of emerging species and lineages of *Phytophthora* including *P. infestans*, *P. ramorum* and *P. kernoviae.* Our team has developed rapid extraction methods with microneedles (MN) and molecular based LAMP assays for pathogen detection. We have developed MN based DNA/RNA extraction and LAMP assays for other important tomato pathogens including tomato spotted wilt, early blight and bacterial spot of tomato. We validated all four LAMP assays in replicated growth chamber experiments with whole plant inoculations and tested the LAMP assay in the field for late blight.

Objective 2. Develop Enhanced near real-time technologies for disease surveillance of late blight;

A disease surveillance and mapping system called USAblight.org has been operative since 2011 to report disease and alert stakeholders; SSR genotyping and sequence based approaches have been used to track spread of modern and historic lineages (FAM-1) of the pathogen and now targeted amplicon sequencing is under development to monitor emergence of new lineages. We have also reconfigured the USABlight website and mapping system and are developing an interactive dashboard using ARC GIS and SAS software to display late blight data in near real-time. A larger data base called the PlantAid database is under development that will allow us to bring in LAMP sensor data into the disease reporting system with a phone app.

Objective 3. Study the population biology and evolution of *P. infestans* on potato, tomato and related Solanaceous species using population genomics and phylogenetic tools

Multiple isolates of six species of *Phytophthora* in the Ic clade have been sequenced including *P. mirabilis*, *P. ipomoeae*, *P. phaseoli*, *P. andina* (haplotypes Ic), the recently described P. urerae, and *P. betacei* from tree tomato in Colombia. We are examining the evolutionary history of the clade using a larger dataset then previous researchers to understand origins and migrations.

Phytophthora species cause severe diseases on food, forest, and ornamental crops. We have developed an Emerging *Phytophthora* T Bas tool. We developed an open access phylogenetic tool using the Tree-Based Alignment Selector Toolkit (T-BAS) for 192 formally described species of *Phytophthora* and 33 informal taxa in the genus *Phytophthora.* The phylogenetic tree uses sequences of eight nuclear genes and was inferred using the RAxML maximum likelihood program. A search engine was developed to identify microsatellite genotypes of *P. infestans* based on genetic distance to known lineages. The T-BAS tool provides a visualization framework allowing users to place unknown isolates on a curated phylogeny of all *Phytophthora* species. The tree can be updated in real-time as new species are described. The tool contains metadata including clade, host species, substrate, sexual characteristics, distribution, and reference literature, which can be visualized on the tree and downloaded for other uses. This phylogenetic resource will allow data sharing among the global *Phytophthora* community and the database will enable users to upload sequences and determine the phylogenetic placement of an isolate within the larger phylogeny and download sequence data and metadata. The database will be curated by *Phytophthora* researchers and is housed on the T-BAS web portal in the Center for Integrated Fungal Research at NC State. The T-BAS web tool can be leveraged to create similar metadata enhanced phylogenies for other Oomycete, bacterial or fungal pathogens.

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

We have deployed the “Emerging Phytophthora T BAS tool https://ristainolab.cals.ncsu.edu/research/an-open-t-bas-phylogeny-for-emerging-phytophthoras/) and it is being used by members of our lab and the broader Phytophthora research community to identify new species. We are also using the tool to make sure archived cultures in our collection are correctly identified. In August 2023, I will participate in the Oomycete Molecular Genetics Network meeting in Lyon France at the International Congress of Plant Pathology and I will talk about the tool and encourage other Phytophthora researchers to use it. I will also be organizing a concurrent session on Emerging Phytophthora where we will discuss detection, genotyping and other means of pathogen surveillance.

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

Adoption of new technologies such as LAMP detection technologies, real time data analytics and mitigation interventions to late blight and other plant disease pandemics requires acceptance by society. In our work, we are also characterizing how human attitudes and social behavior of stakeholders impacts plant disease transmission and adoption of surveillance and sensor technologies. We plan to engage a broad group of stakeholders including scientists, growers, extension specialists, the

USDA APHIS Plant Protection and Quarantine personnel, the Department of Homeland Security inspectors, and diagnosticians in the National Plant Diagnostic Network in a Pandemic Preparedness workshop to be held at NC State in the Plant Sciences Building in April 2023. The workshop participants will respond to plant disease threat scenarios using current methods and with the aid of PAdb. Differences in response and spread of pathogens and stakeholder experiences will be examined.

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.

DEVELOPED AND DEPLOYED TECHNOLOGY TO IMPROVE PREDICTION OF EMERGING PLANT DISEASES: The genus Phytophthora contains many destructive plant pathogens with great impact on agriculture, and Phytophthora plant species represent a significant emerging threat due to increases in plant movement via international trade. There is also the potential for the emergence of new harmful species through evolutionary change. NC State researchers are developing improved detection and surveillance technologies and tools to better understand and manage new species and react more rapidly to new pathogens. Their accomplishments so far include developing smart phone-based assays and a phone app for rapid in-field detection of emerging potentially harmful species; enhancement and reconfiguration of a disease surveillance, mapping, and grower alert system called USAblight.org; ongoing development of an interactive dashboard to display blight data in near real-time; genetic sequencing and evolutionary analysis of species affecting food, forest, and ornamental crops; and development and deployment of a database and web tool that can be used by the research community to identify and classify new species. Adoption of these new technologies and tools will help scientists, growers, Extension specialists, and other stakeholders respond to the spread of plant diseases with increased precision and speed.

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

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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.

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

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

x

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.

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Soil Health Management Practices for value-added CBD Hemp Production in North Carolina

Project Director

Arnab Bhowmik

Organization

North Carolina Agricultural and Technical State University

Accession Number

Soil health management practices for CBD hemp production in North Carolina

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

Our research project addresses the lack of agronomic guidance for hemp varieties grown for cannabinoids under different organic fertility management. In addition, the project examined the reuse of hemp biomass residue as an amendment to improve soil health. Finally, our research seeks to optimize the extraction and purification of cannabinoids.

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 activities that occurred include i) cultivation of different hemp varieties under organic fertility management, ii) whole plant and floral biomass collection, iii) laboratory experiments for the characterization of the impact of hemp biochar and swine manure on soil health, iv) extraction and purification of cannabinoids, v) presentation of results.

During the project, we grew CBD hemp varieties with no organic fertility treatment, under cover crops, compost and cover crop plus compost. During the field trial, we gathered agronomic and soil health data for nutrient analysis at mid-vegetative, late-vegetative, and harvest stages. This helped us to examine the changes in soil biological activity, plant biomass and CBD production. We also collected rhizosphere and bulk soil samples from this trial and a fiber hemp variety trial from North Carolina State University research station at Salisbury to compare the soil microbial community structure and their diversity between CBD and fiber hemp varieties.

To further understand how hemp biomass reuse can improve soil health, we converted hemp residue stalks to biochar and applied it with swine manure or nitrogen fertilizer during a 54-day laboratory incubation. During the incubation, we implemented different temperatures and soil water contents. We measured changes in soil biological activities and soil carbon.

For CBD extraction, we experimented with a wiped-film molecular distillation (WFMD) system for stripping and refining cannabidiol (CBD) from hemp extracts.

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

During the course of this project, two post-doctoral researchers (male and female) were hired. Three master's degree students and six undergraduate students were trained in research techniques, nutrient analysis, processing of plant materials, and oral and written communication. The effort was highly successful, as a master's degree student received a first-place award for best presentation during the Association of 1890 Research Directors conference. This research helped in the professional skill development of postdocs, graduate and undergraduate students on industrial hemp production, soil health management practices and independent research design.

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

The results of our research was presented during the 2022 Small Farms Week held in March and the Small Farms field day. Farmers and interested members of the public had the opportunity to visit the hemp research fields. A poster was also presented by a graduate student during the event. Other groups that beenfited from the project includes hemp processors, small-scale acreage farmers, undergraduate and graduate students.

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.

1. Facility issues: We need access to a secured unit to store hemp biomass from our research. This is a serious issue and will affect the quality of our results.

2. Without access to a greenhouse, we had to procure plants from private companies instead of producing our own. Access to greenhouse space is essential to maintain the hemp varieties (stable genetics) so that we can continue to use them in our long-term field trials.

3. Equipment: Our lab uses chemicals like chloroform and acids to extract components from the soil. The project has experienced a delay in crucial laboratory equipment such as the fume hood.

4. Two New graduate students have been admitted to the program on this project. The students participated in disseminating the research during the annual Smal Farms day at the University farm.

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11. Ashlee George*, Idowu Atoloye, Dipti Rai, Abolghasem Shahbazi, Arnab Bhowmik. Organic Management Practices for Optimal Floral Hemp (Cannabis sativa L.) Production in the Southeastern US. Association of 1890 Research Directors. April 2-5, 2022. (*student mentee poster).

12. Williams, J*., Atoloye, I., Bhowmik, A., (2022). Quantifying the effect of biochar sorption on soil enzyme activities. Association of 1890 Research Directors. April 2-5, 2022. (*student mentee oral presentation).

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17. Williams, J*., Slocum, A., Atoloye, I., Shahbazi, A., Bhowmik, A. (2021). Quantifying the Effects of Biochar Sorption on Soil Enzyme Activities. Soil Science Society of America (SSSA), Salt Lake City, UT. (*student mentee poster).

Improving management of plant-parasitic nematodes through applied epidemiology

Project Director
Adrienne Gorny
Organization
North Carolina State University
Accession Number
1022484

Annual Result: Improving management of plant-parasitic nematodes through applied epidemiology

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

Plant-parasitic nematodes (PPN) are soilborne plant pathogens that can cause significant reductions in crop yield and quality. In addition, PPN impact agricultural production by requiring additional production inputs to mitigate damage, such as chemical nematicides, fertilizers and irrigation, sanitation activities, and soil sampling and diagnostics activities. Current management tactics for PPN include chemical nematicides, crop rotation, use of resistant crop genotypes where available, and cultural practices (e.g. cover cropping, aerobic soil disinfestation, and tillage). Decisions on whether to undertake a nematode management tactics should be driven by nematode population densities and the risk these densities pose (in combination with other production factors) to crop loss. Yet challenges in PPN diagnostics, identifying economic thresholds, and gaps in knowledge about biological, environmental, and edaphic factors influencing nematode epidemics currently limits full implementation of sound decision making. This project seeks to address these challenges by investigating nematode biological characteristics, performing studies to model crop loss as a function of initial population, evaluate optimal management tactics, and make advancements in DNA-based molecular diagnostics of PPN.

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.

Accomplishments were made under each project objective, as described below:

1. *Advance scientific knowledge of PPN epidemiology through investigating biological characteristics of emerging nematode pathogens, abiotic factors contributing to epidemics, and spatiotemporal dynamics of PPN populations.* Biological characteristics regarding the host range of *Meloidogyne enterolobii* (the guava root-knot nematode) were evaluated by determining which plant weed species this nematode could infect and if the weed host range was similar or different to that of *Meloidogyne incognita* (southern root-knot nematode), which is considered more widespread than *M. enterolobii*. Briefly, seeds of ten common plant weed species were obtained from a collaborator and sown in the greenhouse. Three weeks after planting, weed seedlings were inoculated with standard rates of either *M. enterolobii* eggs or *M. incognita* eggs. After inoculation, weed plants were maintained in the greenhouse for approximately 60 days, after which they were destructively harvested and evaluated for evidence of infection. It was found that of the ten weed species evaluated, the host range of *M. enterolobii* and *M. incognita* appeared similar, with the exceptions of purple nutsedge and prickly sida, which were both demonstrated to be host to *M. incognita*, but non-host to *M. enterolobii*.

2. *Model the relationship between PPN population densities and crop loss in agronomic and vegetable crops, and develop economic thresholds.* To reevaluate and explore further crop loss as a function of nematode population density, a second repetition of the greenhouse screening experiment described in the previous report was started during the current reporting period. Briefly, this experiment evaluated the response of cotton to the root-knot nematode M. enterolobii. Four unique genotypes of cotton were evaluated under four nematode population densities (23,000 eggs/pot; 13,000 eggs/pot; 7,000 eggs/pot; and non-inoculated controls). Plants are being maintained in the greenhouse and evaluated for growth and node number on a biweekly basis. Plants will be destructively harvested at 15 weeks post inoculation and boll yield, boll number, root galling, and root weight was evaluated. Data will be analyzed using Analysis of Variance and mean separation.

3. *Investigate integrative pest management strategies for robust control of PPN.* Integrative pest management involves use of multiple disease management strategies to achieve a reduction in the pathogen population and reduce crop loss due to the pathogen. Two management tactics were explored under during the reporting period under this objective, including chemical control and non-host rotational crop control. Trials for managing PPN, particularly *M. enterolobii*, through the use of chemical nematicides in sweetpotato, cotton, soybean, corn were performed during the reporting period (growing season 2022). Field sites with a history of *M. enterolobii* were selected for sweetpotato, cotton, and soybean trials, and a site infested with sting nematode (*Belonolaimus longicaudatus*) was selected for a corn trial. Fumigant and non-fumigant products were evaluated for effect on nematode population density and crop yield. Crops were planted and maintained for the duration of the season. Early season and mid-season soil nematode populations were quantified. At harvest, data were collected on yield, soil nematode populations, and incidence of galling damage (sweetpotato) or root galling severity (cotton, soybean). Data were analyzed to assess the efficacy of each product on reducing incidence of nematode damage, reducing soil populations, and increasing marketable yield. Results from this reporting period have been presented to stakeholders at Extension and outreach events, used to update Agricultural Chemicals Manuals, and used to develop individual management recommendations. A field trial to evaluate the utility of non-host rotational crops in reducing populations of M. enterolobii was performed. Four crops, including soybean

(host to M. enterolobii), peanut (non-host), tobacco (host), and corn (non-host) were planted in long strip plots during the reporting period at a site known to be heavily infested with *M. enterolobii*. The crops were maintained for the duration of the season. At the end of the season, soil samples were systematically collected from each planted area and root-knot nematode populations quantified. It was found that root-knot nematode populations under the peanut treatment were significantly lower than those populations under the tobacco or corn treatments. Further, populations under the peanut treatment were numerically lower than those under the soybean treatment, although the reduction was not statistically significant.

4. *Advance molecular- and DNA-based methods for detection and quantification of PPN.* New collaborations and experiments for researching a rapid, species-specific test for *M. enterolobii* in sweetpotato. A set of recombinase polymerase amplification (RPA) primers and fluorescently labelled probe for species-specific detection of *Meloidogyne enterolobii* (Subbotin et al. 2019) were identified through the literature and tested for specificity and sensitivity to pure egg samples of two North Carolina isolates of *M. enterolobii*. To evaluate specificity, the RPA reactions were performed using reagents from the TwistAmp® exo kit in a 50 µL total reaction volume. Amplification reactions were conducted as suggested by the reagent manufacturer and Subbotin et al. (2019). Reaction mixtures were incubated at 39°C for 24 min in a BioRad CFX Connect Real-Time System, with fluorescence reading every 20 sec. Replicated testing revealed that the primers and the probe was species-specific to *M. enterolobii* and produced a positive signal in both NC isolates of *M. enterolobii* tested, while negative signals were observed in reactions containing other, non-target root-knot nematode species. We believe the RPA primers and reaction conditions will work well for *M. enterolobii* isolates from distinct geographic regions of North Carolina. To evaluate sensitivity of the assay, RPA primers and probe were screened against different concentration of *M. enterolobii* within the reaction mixture. A series of samples containing either 10,000 *M. enterolobii* eggs, 4 individual nematodes pooled, or 1 individual nematode were processed for DNA extraction using a standard Proteinase K DNA extraction procedure. DNA samples were then subjected to RPA amplification. The non-target negative control consisted of 4,000 *M. incognita* eggs. The RPA reaction was positive for all concentrations of *M. enterolobii*, and the negative control did not amplify (Figure 1). This indicates the RPA method is highly sensitive when using a fluorescence detection, capable of detecting 1 *M. enterolobii* individual in a sample.

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

The target audience of this project consists of the scientific and agricultural communities. Agricultural stakeholders (including farmers, produce packers, industry leaders, and crop consultants) and Extension affiliates (including extension plant pathologists, nematologists, plant breeders, crop protection specialists, and cooperative extension personnel) were engaged through project outputs of Extension presentations, publications, disease management information, popular press articles, and videos. Agricultural stakeholders were also involved in this project through on-farm research involving management of nematodes. This target audience benefited from the project activities through updated PPN nematode management recommendations, farm-specific nematode evaluations, and increased knowledge of distribution of PPN. Scientific audiences were engaged through attendance and presentations at conferences and discipline-specific meetings, including the American Phytopathological Society 2022 Annual Meeting and the Society of Nematologists 2022 Annual Meeting. The scientific community was also engaged by submitting manuscripts to peer-reviewed academic journals. This scientific audience benefited from project activities through sharing and review of new research findings. In addition to these target audiences, this project engaged graduate students and summer research interns in plant pathology and nematology, who benefited from project activities through career specific training.

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

A crucial focus of this project is research towards the biology, distribution, and management of *Meloidogyne enterolobii* (the guava root-knot nematode) in North Carolina and the Southeastern United States. This species an invasive and recently nematode in the southeastern United States, where it has significantly impacted agricultural production. *Meloidogyne enterolobii* is a highly aggressive species and is able to overcome host resistance genes in crops such as tomato, soybean, and cotton that are used in controlling species of the *M. incognita* species complex. Experiments, surveys, and field trials in this project were designed and carried out to gained more knowledge about this nematode species in North Carolina and the Southeastern US. Identifying and optimizing management tactics for *Meloidogyne enterolobii* in vegetable and row crop systems will allow producers to effectively manage this nematode pest, which will benefit the broader public by ensuring a healthy and robust food supply, produced in an environmentally and economically sustainable manner.

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.

IDENTIFIED MORE EFFECTIVE APPROACHES TO CONTROLLING PLANT-PARASITIC NEMATODES: Plant-parasitic nematodes (PPN) are soilborne plant pathogens that can cause significant reductions in crop yield and quality, and controlling them often demands the use of expensive, time consuming, and environmentally damaging methods. To close current knowledge gaps and support optimized management of PPN, NC State researchers are investigating nematodes' biological characteristics, modeling crop losses in relation to PPN populations, and evaluating management methods. Through these studies, they have identified new relationships between PPN species and certain weed species and identified a new method for highly accurate detection of a high-impact emerging PPN species (the guava-root nematode). They have also developed and presented new PPN management recommendations at Extension and outreach events, through updates to agricultural chemical manuals, and through individual management recommendations. By supporting effective management of this potentially devastating crop pest, these insights benefit not only the scientific and agricultural communities but also the national food supply and consumers as a whole.

delete

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

x

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.

x

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

x

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

x

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.

x

Developing context-driven decision-support framework to improve region-scale management of animal byproducts

Project Director

Mahmoud Sharara

Organization

North Carolina State University

Accession Number

1022103

Developing context-driven decision-support framework to improve region-scale management of animal byproducts

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

My project focuses on improving animal manure and byproduct utilization through region-specific considerations to inform technology and strategies adoption. This approach relies on (1) collecting robust, and high-quality datasets on material flows and economic cost associated with established and manure processing technologies and management decisions, (2)

quantifying environmental and economic impacts of these technologies and decisions on air, soil, and water quality as well as the economics of manure management, and (3) developing optimization frameworks as decision-support tools to guide technology and management decisions to improve environmental, and economic outlooks for animal production system.

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 past reporting period, my team completed and published a study that details the use of swine lagoon sludge as ingredient in producing value-added soil amendment (compost) using no-cost (or low-cost) ingredients (https://doi.org/10.1016). The study also reports the greenhouse gas (GHG) emissions associated with this utilization approach to facilitate life cycle assessment (LCA) of this utilization pathway. Concurrently, we are devleoping a technoeconomic model for the adoption of this technology to facilitate side-by-side comparison with existing strategies.

- During the past reporting period, my team presented a preliminary study (https://lpelc.org/evaluating-full-scale-greenhouse-systems-for-lagoon-sludge-drying-and-pathogen-reduction/) detailing the performance of a pillot-scale greenhouse drying system (currently operational for research purposes @ NCSU Lake Wheeler Farm Facility). We are integrating the technology performance data into a framework as a viable alternative for regional optimization.

- During the past reporting period, I led an effort to develop a spatially-explicit inventory of nutrients geneartion and removal potential in major riverbasins in North Carolina. This effort utilizes a variety of open-access and published datasets to arrive at watershed-level (HUC level-12) assessment of nutrient flows. This inventory is intended to inform frameworks for export and utilization to minimize adverse environmental impacts, maximize economic revenue, or both. The inventory will be published along with a peer-review publication detailing its development, utilization, and assumptions to inform use by other resaerch teams as well.

- During the past reporting period, we conducted a study to collect field data describing energy inputs and material properties during sludge excavation from swine lagoons as well as greenhouse drying of sludge solids. The data has been utilized to develop a series of empirical models to predict system performance as well as to facilitate technoeconomic model (TEA) and life cycle assessment (LCA) of this sludge management approach in comparison to baseline strategies (i.e., agitated slurry hauling, polymer dewatering and hauling). The data is being finalized and will be presented in national meeting (ASABE AIM) this summer.

- During the past reporting period, with funding from NC State University Research and Innovation Seed Funding Program (RISF), I led the development of a simulation tool to help predict the impact of future climate on animal production using lagoons and storage ponds. The model utilizes a mass balance approach to simulate water balance along the barn-lagoon-field(s) system on a daily timestamp by assuming different operator (farmer) priorities. The tool is currently in beta testing and I am in the process of seeking external funding to augment the tool as a farm-level planning tool. We envision this tool as a critical aid in informing nutrient cycling on the farm to minimize environmental losses as well as to help evaluate the value of advanced technologies (e.g., slurry acidification, lagoon covers) to reducing environmental emissions.

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

- During the past reporting period, I was invited to present to the National Pork Board (NPB) on insights gained from our study published on nutrient imbalance in animal agriculture systems (doi: 10.13031/ja.14661). As a byproduct of this opportunity, I participated in the development of a Request for Proposal (RFP), titled "*A Systems Approach to Understanding the Nutrient Cycle Across the Pork Ecosystem*". Since then, I was also invited to participate as a co-investigator in a proposal that was since funded by NPB and is currently ongoing. This team encompasses experts along the swine value-chain, i.e., genetics, nutrition, animal environment, manure management, and crop/soil scientists to develop an integrated strategy to improve nutrient cycling.

- During the past reporting period, we produced a virtual tour/learning aid (https://www.youtube.com/watch?v=MD4gdLO1yAE) detailing the concept of greenhouse drying and building on testimonies from various stakeholders to help the audience understand system operation and considerations when adopting it. As a result of the data gathered and infromation shared around this strategy, several farms in NC are adopting this technology, with technical assistance from a private third-party company (Phinite). to facilitate sludge management and export.

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

During the past reporting period, I presented in various venues where the following were participants: animal producers, extension agents, technical support teams, USDA NRCS and USDA ARS personnel, local soil & water conservation district employees. In these presentations, I communicated evidence-based information on the performance of novel technologies and their potential to improve manure management. I also highlighted the environmental benefits gained from their adoption. In addition, through engagement with local and national media/trade magazines, I provided research updates to help broader food production audiences and other interest public in learning about opportunities to improve nutrient cycling in food animal systems.

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.

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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.

ENHANCED SUSTAINABLE, PROFITABLE MANAGEMENT OF ANIMAL BYPRODUCTS: Animal production creates large amounts of waste that can damage the environment and create significant hazards and financial burdens for farmers. To help farmers run more profitable, sustainable animal production operations, NC State researchers have discovered new ways to use animal manure and other animal production byproducts. Milestones include the publication of a study detailing the use of swine lagoon sludge to create low-cost compost materials, presentation of a preliminary study into full-scale greenhouse systems for processing lagoon sludge into a compact and exportable form, a virtual tour and learning aid to help stakeholders understand and adopt this greenhouse sludge drying technology, and the development of a simulation tool to help predict impacts of future climate conditions on animal production lagoons and storage ponds. These insights and practical tools are a critical means for farmers to minimize environment-related hazards and the environmental impact of their operations while also enjoying reduced fertilization costs.

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

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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.

x

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

x

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

x

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.

x

Enhancing Poultry Production Systems through Emerging Technologies and Husbandry Practices

Project Director
Lingjuan Li
Organization
North Carolina State University
Accession Number
1020450

Annual Result: Enhancing Poultry Production Systems through Emerging Technologies and Husbandry Practices

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

Most of US broilers are produced in Southeastern states where climate change increases the incidence and severity of heat waves, compromising broiler performance and welfare. This research is to develop transformative solutions to make the broiler industry sustainable under changing climates.

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 control chamber study and field investigation, this project assesses heavy broiler heat and moisture production; environmental factors a?ecting broiler behavior and welfare; definition of broiler normal behavior; objective measures of broiler welfare using image and vocal sensing techniques; optimization of broiler grow out housing ventilation and environmental control system design through PLF. Two dynamic air velocity (AV) treatments (High and Low) were applied in three chambers per treatment and 44 broilers per chamber from age 35~61day in hot and humid summer conditions. Capturing thermal images of the birds' surface temperatures (Ts), recording videos of their activities, and measuring various environmental parameters such as T, RH, and AV with different sensors were collected during the experiments. Results showed that the average Ts of the broilers was 35.89±2.37?, and the birds exposed to high AV had significantly lower Ts than those exposed to low AV (p<0.05). A regression model was developed (R2=0.512) to predict heavy broilers' Ts based on age, T-RH index, and AV. In addition to reducing the Ts of heavier birds, the high AV also resulted in more birds eating, standing, and walking than those in the low AV group. The current market-sized broiler produces 5~20 W/kg sensible heat and 4~37 g/hr-kg moisture depending on thermal environmental conditions. High AV can help birds regulate their comfortable body temperature in heat-stressed summer by releasing excessive heat into the surrounding environment. In addition, a computational fluid dynamic (CFD) modeling approach, a retractable baffle was designed to mitigate the heat stress on the heavy broiler in the existing facilities by increasing AV at the bird's level. Results indicated that in a broiler grow-out house with dimensions of 144.8 m long and 15.2 m wide, 2.4 m sidewall height, and 3.4 m ceiling peak, nine baffles placed at 12.2 m intervals, at 30 degree inclination from the ceiling, 1.524 m above the floor surface would increase the average AV to 50% at bird's height without exceeding the recommended static pressure guideline.

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

This work advances our understanding of high air velocityy impact under di?erent T/RH conditions on the performance and welfare of heavy broilers in age between 35-61d. The study study also filled the research gap by updating fifty years old heat production and moisture production of modern broilers. It will also provide optimal engineering design of a cost e?ective retractable ba?le system to mitigate heat stress problems without significantly modifying current structures. This study will also contribute to the enhancement of animal well-being, which is vital for the U.S. broiler industry to remain competitive in the world's food production market.

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

Integrating environmental parameters with animal responses to the environmental conditions is the next step to define animal comfort conditions and dynamically maintain such conditions by developing AI-powered control strategies, which will lead to resilient production system to the climate change. The research results have been disseminated through peer reviewed publications and conference report. Students, especially underrepresented students were trained to be next generation workforce for the industry.

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.

Thesis/Dissertations

1. West, D.R. Litter Characteristics, Ammonia Emissions, and Leg Health of Heavy Broilers as Impacted by air Velocity Treatments: A chamber study. Master's thesis, North Carolina State University, Raleigh, NC, USA, 2020.

2. Akter, S. Heat Stress Mitigation for current marker-sized heavy broilers under summer conditions. PhD. dissertation, North Carolina State University, Raleigh, NC, USA, 2023

Publications

1. Akter, S. Y. Liu, B. Cheng, J. Classen, E. Oviedo, L. Wang-Li*. 2022. Impact of Air Velocity Treatments under Summer Conditions: Part III-Heat and Moisture Production, In review

2. Akter, S. Y. Liu, B. Cheng, J. Classen, E. Oviedo, L. Wang-Li*. 2022. Impact of Air Velocity Treatments under Summer Conditions: Part II-Heavy Broilers' Behavior Responses. *Animals*. 2022,12,1050. https://doi.org/10.3390/ani12091050

3. Akter, S. Y. Liu, B. Cheng, J. Classen, E. Oviedo, L. Wang-Li*. 2022. Impact of Air Velocity Treatments under Summer Conditions: Part II-Heavy Broilers' Behavior Responses. *Animals*. 2022,12,1050. https://doi.org/10.3390/ani12091050

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.

LAID GROUNDWORK FOR COST-EFFECTIVE, RESILIENT METHODS FOR REDUCING HEAT STRESS IN POULTRY: Most US broilers are produced in southeastern states where climate change increases the incidence and severity of heat waves, compromising broiler performance and welfare. To develop transformative solutions for broiler industry sustainability, NC State researchers have conducted an assessment of the environmental factors impacting broiler behavior and welfare, advancing the understanding of how a technology called a high air velocity system can help birds regulate their body temperature under hot and humid conditions by releasing excessive heat into the surrounding environment. They also gained insights that will inform the optimal engineering design of a cost-effective air velocity enhancement system for reducing heat stress in flocks without significantly modifying current production structures. This research will not only improve the climate change resilience of poultry production operations but also enhance animal wellbeing, and it may eventually inform artificial intelligence (AI)-powered control strategies for environmental control in animal production. The research results have been disseminated through peer-reviewed publications, a conference report, and specialized training for students.

DELETE

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

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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.

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

x

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

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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.

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Integrative Research for Sustainable Crucifer Production: Pest Management, Soil Health and Profitability

Project Director
Louis Jackai
Organization
North Carolina Agricultural and Technical State University
Accession Number
1019922

DELETE

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

This project aims to develop synergistic or additive management of pests of collard and kale by deploying resistant varieties, trap crops, and visual action threshold-driven biorational insecticides in a grower-friendly and ecologically sound approach. The overall purpose of this project is to increase system profitability and potential sustainability by integrating the effective tactics developed in this project. The harlequin bug (HB) (*Murgantia histrionica*) is considered an important economic pest of cruciferous crops in the southern United States. Adults and nymphs use their piercing and sucking mouthparts to suck the sap out of the leaves and stems of their host plants, leaving behind cloudy white blotches (necrosis) on the leaves that coalesce and drastically reduce the quality of the crop; eventually these lead to severe damage and eventual death of the plant. Many growers resort to the use of synthetic insecticides as the default measure to control harlequin bugs in order to protect the marketability of their crop. Synthetic insecticides and their residues have well- documented impacts on both human and environmental health, and most consumers are opposed to their use.

There is limited information regarding other management tactics on crops grown by small farmers, for example resistant varieties, treatment thresholds, use of crop manipulations as in trap crops for the management of pests. Little is known on resistant varieties of collard and kale against HB. This hiatus in agricultural technology makes growers more reliant on high risk insecticides. At the minimum, if insecticides were going to continue to be used, action thresholds for application need to be developed to reduce the environmental footprints of their residues.

To address above mentioned challenges in managing HB on organic collard and kale we designed the following objectives.

- Objective 1. Screen commercial collard and kale varieties for useful levels of resistance (R) to Harlequin Bug (*Murgantia histrionica*, L), and determine the relationship between glucosinolate (GLS) content and observed resistance.

- Objective 2. Determine the occurrence of synergistic or additive pest management effects using resistant (R) collard and kale varieties (from Obj. 1) with/without trap crop; measure GLS content over time (through vegetative and bloom stages) in a mustard trap.

- Objective 3. Determine the optimal visual leaf damage or infestation level (visual action threshold – VAT) that warrants insecticide treatment (using an organic mixture with organic and low-risk conventional insecticide) and measurement of the interaction of straw mulch and ICW incidence.

- Objective 4. Assess the economic feasibility and profitability of the recommended management practices from objectives 1-3.

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 summer of 2022, we conducted a varietal trial on kale and collard for resistance to the Harlequin bug (HB). We also ran laboratory assays from fall 2021 through fall 2022 to determine HB growth and development on the most resistant collard varieties and on four mustard varieties for which we studied the relative attractiveness of HB to their different growth stages – vegetative and flowering. In the field, we counted number of HBs (eggs, juveniles, and adults), measured leaf damage, sugar and chlorophyll content, and marketable leaf yield; in the lab we collected fitness data to help understand which variety supported growth best. We identified six resistant (moderate to high levels) kale and six of collard. In one resistant collard, the insect did not survive. These will be studied further. In the mustard assays the flowering stage was most attractive to HB and supported growth of the insect the best. In addition, we conducted chemical analytical tests to provide a more in-depth understanding of HB attraction to mustards and how to manipulate this for more effective, non-chemical HB management. In the summer of 2022, we completed a field trial to determine the treatment visual damage action threshold (AT) to reduce insecticide application, even if it were with biorational products which are also more expensive than synthetic products. An AT level of 2 was determined to be most effective and was comparable to a calendar (weekly) spray application that served as the control. In addition, we added straw as a treatment in the AT experiment to evaluate the effects of straw mulch on the caterpillar population. There were only minor differences except that the straw kept the collard cleaner when harvested.

The project met the following expectations. 'Starbor F1', VBC", "DBCS", "WIN" kale and 'Cascade Glaze', "Sexy Mama", "Ole Alabama" and "Yellow" collard were the varieties most resistant to HB damage; the mustard flowering stage was the most attractive plant stage to the HB. These results will be used in developing an effective HB trap cropping system adaptable to small farms for which we already have a blue print. The best AT damage level for insecticide application was 2 (scale of 5). This will dramatically reduce the need for insecticide input in collard or kale production.

In addition, significant progress has been made on the specific glucosinolates responsible for the attraction and arrestment of HB. We also plan to evaluate the real-time variation of glucosinolate levels in collard, kale, and mustard trap varieties during plant growth.

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

Benefits to small growers: Finding resistant varieties of kale and collard against HB and identifying a successful mustard trap crop variety at the best phenological stage will help devise effective HB management strategies in a trap cropping system. This will reduce dependence on pesticides for HB control. Furthermore, the results from objectives 2 and 3 will allow growers to decide and make appropriate judgments on when to spray to control HB and caterpillars on the crop. These results will help the grower to reduce the insecticide application, increase profits, and improve yield while maintaining environmental safety and conserving biodiversity such as natural enemies.

Benefits to research and extension community: Exploring the deployment of glucosinolate-driven traps crops at different phenological stages would generate interest in trap crop use for other systems besides crucifers to reduce cost and increase food safety and farm income.

Benefits to students and staff: Increased knowledge and skillsets in this new and exciting area using a new digital techniques such as spectroradiometer for measurement of spectral data.

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

The way the broader public will be benefited from this project will be seen at the grocery store with synthetic pesticide residues on agricultural 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.

We did not encounter any major problems in conducting the various experiments, except for personnel attrition and difficulty in hiring replacements which made field work and laboratory research management excessive for available staff.

Opportunities for training and professional development:

The project provided funding for two MS graduate students to complete their education and research for graduation. The project also provided research staff and students the opportunity to attend meetings and present project research findings, for example at the ARD conference in Atlanta, GA, the South Carolina Entomological Society Annual Meeting in Georgetown, SC, and the joint Annual Meeting of the Entomological Societies of America, that of Canada and of British Columbia in Vancouver, Canada.

Dissemination to communities of interest:

We were able to present our findings at different scientific meetings, as mentioned above, farm visits by growers, and thus able to disseminate information of our research and its findings to the growers at NCA&TSU small farmer field days. Three journal papers will be forthcoming.

Plans for the next reporting period:

We are still planning to conduct several lab experiments and GLS analysis to identify the most effective mustard trap crop phenological stage and the associated GLS profiles. In addition, lab experiments will be repeated to confirm growth and development events recorded in this reporting period.

We plan to complete the second field season (summer 2023) experiment to confirm the visual action threshold (objective 3) and conduct the overall integration of each tactic so as to assess the economic feasibility (objective 4) of the proposed model.

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. #1 - To characterize GRE and OPE: The major bioactive compounds in GRE were successfully characterized during Years #1, #2, & #3 of the project. Also, the **OPE** was successfully prepared from dried onion peels through various extraction methods.

Obj. #2 - To determine best inclusion levels to boost immunity in broiler chickens: In a 6-week live broiler chicken experiment that was conducted during Year #2, graded levels of GRE (between 0.37% and 3%) was incorporated into the diet. Biological samples such as the **liver**, **intestinal segments**, **breast muscle**, and **blood plasma** were collected and appropriately stored until time for analysis.

During Year #3, the effect(s) of dietary GRE on "**liver** lipid metabolism" and "**intestinal** oxidative stress" were investigated. Results showed that i) dietary GRE up to 0.75% reduced ($P < 0.05$) **abdominal fat pad** (as desired in the poultry industry) by increasing liver triglyceride concentration, and that ii) dietary GRE up to 1.5% had higher ($P < 0.05$) antioxidant capacity, higher goblet cell #s and mucin gene expression compared to antibiotic BMD. These findings indicate that GRE enhances bird health through its antioxidative and antilipogenic effects. During Year #4, we will conduct live chicken experiment(s) to determine the optimum dietary level of **OPE** that will comparatively enhance immune function and growth performance to a similar degree as the antibiotic, bacitracin methylene disalicylate (BMD).

Obj. #3 - Evaluate efficacy of optimum dietary GRE & OPE levels in reducing intestinal *Salmonella* spp. in broilers: Live broiler chicken trials to investigate this objective are scheduled to be conducted during Year #4 of the project.

Obj. #4 - Determine metabolomic signatures of GRE & OPE that protect against *Salmonella* spp: During Yr #3, biotransformation of GRE gingerols & shogaols into their metabolites in the **breast tissue** and **plasma** samples collected from Obj. #2 was studied using HPLC & mass spectrometry. In breast meat, all gingerols, shogaols, and their metabolites were present in both free and conjugated forms, and a dose-dependent absorption was observed. This implies that the bioactive gingerols & shogaols in GRE were likely involved in improving bird health through their antioxidative and antilipogenic activities.

Obj. #5 - Effect of dietary GRE & OPE on meat quality: Breast meat quality analysis was performed on **breast meat** samples collected from Objective #2. **During Year #3**, total lipids in breast meat samples was extracted and derived as fatty acid methyl esters. Results showed that the total lipid concentrations in the breast meat of all chicks fed graded levels of dietary GRE (0.375, 0.75, and 3%) was higher ($P < 0.05$) than those of control meat samples. It was hypothesized that dietary GRE probably decreased the oxidation products in the breast meat and increased the extraction of total lipids, thereby reducing the accumulation of the abdominal fat pad as observed in Objective #2.

The derived fatty acid methyl esters samples have been kept frozen at −80°C for the determination of fatty acid composition by HPLC during Year #4.

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

Results showed that GRE can be supplemented into broiler chicken diets to reduce oxidative stress and accumulation of fat pad, thereby enhancing overall bird health. 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.

1. During Year 3 (2021-2022) of this project, 4 undergraduates, 7 graduate students, 1 Postdoctoral researcher, and 1 research associate all belonging to underrepresented minority groups were trained on various experimental procedures and analyses.

2. Two MS students, Olubunmi Apalowo and Cayla Steemer successfully defended their thesis in summer 2022.

3. Training on preparation of abstracts and presentation slides and posters.

4. Graduate students received specialized training on how to perform some biochemical and molecular analyses, execute live chicken trials, and collect biological samples for downstream analyses. This involved hands-on training on the following;

- Training on Gene expression analysis procedures (i.e. RNA isolation, Determination of RNA quality, cDNA synthesis, CDNA quality, Primer design, Thermal gradient analysis, quantitative RT-PCR analysis, and data analysis)
- Training on Differential leukocyte counts and Enzyme-linked Immunosorbent assay.
- 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.

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.

Changes or problems encountered in approach:

1. Research Associate (Lab Manager) position was vacant for about 8 months (i.e. January 2022 to mid-August 2022).
2. Postdoctoral Research Associate position has been vacant from July 2022 to date.
3. One Graduate student (George Dosu) discontinued his Ph.D. program in August 2022.
4. Due to a change in the Analytical Laboratory methodology, Dr. Da Silva and undergraduate student faced difficulty in extracting methyl esters from chicken breast meat for fatty acid analysis.
5. Prior delays due to COVID19.

6. I estimate that this project is at least 1 year behind the original schedule.

Professional Development Opportunities Provided:

1. Dr. Fasina and 4 Graduate students attended the 111th Poultry Science Association Annual Meeting, July 11-14, San Antonio, Texas.

2. Students participated in a weekly NSF crosstraining program to learn about the role of biostatistics, bioinformatics, and computational modeling in scientific practice.

Dissemination of results to communities of interest:

Refereed Journal Publications (***Denotes Student contribution**)

1. Adetunji, A., Casey, T., Franco, J., Shah, D., & Fasina, Y. (**2022**). Proteomic Analysis of the Effect of *Salmonella* Challenge on Broiler Chicken. Molecules (Basel, Switzerland), 27(21), 7277. https://doi.org/10.3390/molecules27217277 **Impact Factor= 4.927**

2. Kimminau, E. A., Karnezos, T. P., Ko, H., **Fasina, Y.**, & Kim, W. K. (**2023**). Phytogenic blend administered through water impacts Salmonella infection in broiler chickens. Journal of Applied Poultry Research, 32(1), 100320. https://doi.org/10.1016/j.japr.2022.100320 **Impact Factor= 2.162** (**NOTE: this manuscript was accepted in 2022**).

Abstract Presentations at Professional Meetings (***Denotes Student Contribution**)

1. Olubunmi Apalowo*, Adedeji Adetunji, and Yewande. Fasina. **2022**. Influence of Dietary Ginger Root Extract on the Expression Levels of Antioxidant Defense Enzymes and Mucin Genes in the Intestine of Broiler Chicks. Presented at the 111th Poultry Science Association Annual Meeting, July 11-14, San Antonio, Texas.

2. Paul Omaliko*, Emily Kimminau, Adedeji Adetunji, Tunde Ogundare* and Yewande Fasina. **2022**. Effect of a novel phytogenic water-soluble blend on intestinal Salmonella colonization and growth performance of broiler chicks. Presented at the 111th Poultry Science Association Annual Meeting, July 11-14, San Antonio, Texas.

3. 0Shuwei Zhang, Yewande Fasina, George Dosu*, and Shengmin Sang. Absorption and metabolism of ginger compounds in chicken. Presented at the **2022** American Chemical Society Virtual conference, August 21-25.

4. Richardson*, J., T.O. Obanla, M.M. Khan, and Y. O. Fasina. (**2022**). Effect of Salmonella Enteritidis on the expression of trefoil factor 3 in cecal tonsils of broiler chicks. Presented at the Association of 1890 Research Directors (ARD) Symposium, April 3-6, Atlanta, GA.

5. Dosu*, G., T.O. Obanla, and Y. O. Fasina. (**2022**). Dietary Ginger Root Extract modulates fecal concentrations of Indicator Microorganisms in Broiler Chickens. Presented at the Association of 1890 Research Directors (ARD) Symposium, April 3-6, Atlanta, GA.

6. Yewande Fasina, George Dosu, Tunde Ogundare, and Ikenna Enenya. **2022**. Avian Influenza: Control Measures and Emergency Preparedness. Presented at the 19th Annual Small Farms Field Day, June 23, North Carolina A&T State University, Greensboro, NC.

7. Chandler Dix*, Jaden Payne*, Jannatul Ferdaus*, Yewande Fasina, and Roberta Claro da Silva. **2022**. Evaluation of the effect of Ginger root extract on meat quality of broiler chickens. Presented at the 11th Annual CAES Student Showcase of Excellence (NC A&T State University), September 7, Greensboro, NC.

Continuation Plan for Remainder of Funding Cycle 2022-2023:

OBJECTIVE #1: Characterization of bioactive compounds and antioxidant potential of onion peel extract (**OPE**).

1. 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).

2. Determine the antioxidant potentials of OPE.

OBJECTIVE #2: Determination of the optimum inclusion level of onion peel extract (**OPE**) that will enhance **immunocompetence** in broiler chicks.

1. Lipid analysis of liver and plasma samples collected.

2. Determination of the expression levels of mucin and antioxidant genes in the intestine.

3. Histological evaluation of intestinal villi mucosal morphometry.

4. 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.

1. Execute *Salmonella* challenge trial to determine efficacy of **GRE** in reducing intestinal *Salmonella* spp. colonization.

2. Execute *Salmonella* challenge trial to determine efficacy of **OPE** in reducing intestinal *Salmonella* spp. colonization.

3. Analyses to be done for both GRE & OPE experiments include the following;
    1. Enumerate ceca *Salmonella* concentrations and liver invasion by *Salmonella*.

    2. Determine Innate Cytokine gene expression levels will be determined by qRT-PCR

    3. Proteomics profiling of Spleen will be done.

    4. Metagenomic profiling of gut microbiota will be done.

    5. Determine plasma *Salmonella* IgG concentrations.

OBJECTIVE #4: Metabolomic identification of bioactive compounds of GRE and OPE and their metabolites that enhance resistance to intestinal *Salmonella* spp. colonization in broiler chickens.

1. Determination of GRE bioactive compounds and metabolites in ceca milieu, ceca tissue, plasma, and breast meat to correlate highly sequestered bioactive compounds and metabolites in these samples to immune function data.

2. Determination of OPE bioactive compounds and metabolites in ceca milieu, ceca tissue, 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.

1. Gas chromatography analysis of fatty acid composition of breast meat from GRE chickens.

2. 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 the Poultry Science Conference (in July, 2023) and the International Poultry Scientific Forum in January 2024.

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

One- versus Two-layer of Plastic Covers for High Tunnel Tomato Production

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

High tunnels are season extension tools that provide opportunities for small, limited resource farmers to extend the growing and harvesting seasons, thus ultimately increase profitability. It has been debating, however, 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 examed 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.

Major activites:

- We planted Big Beef and Rebelski (hybrid cultivars), and Brandywine (heirloom cultivar) slicer tomatoes in March in 3 single-layer (two organic , one conventional) and 3 double-layer plastic covered (two organic , one conventional) high tunnels. In each high tunnel, half of the plants were planted in plant beds covered with black plastic mulch and another half without.

- We collected microclimate, plant growth and yield data; collected fruit samples from Rebelski and Brandywine to measure fruit quality indicators such as pH, titratable acidity, total soluble solid, lycopene and color; and collected production inputs (materials and labor) and daily market tomato prices to create enterprise budgets.

- Two graduate students were scheduled to defend their thesis and graduate at the end of fall semester.

- We offered one field day at A&T University Farm in June and another at the Small Farm Unit of NCDA Cherry Research Farm in July.

Achievements:

Objective 1: Last year results showed that double layer plastic enhanced plant growth but not the yield. Plastic mulch worked independently regardless of the layers of plastic on HT tomato yield and will be a recommended practice.

- Data collection of current season continued through September and the preliminary results are consistent with the results from last year, although tomato cultivars may respond differently to the plastic covers.

- Our field days reached over 312 small farmers and extension educators.

Objective 2: All tasks were completed. We found that the quality attributes of tomatoes including color, pH, acidity and nutrient contents of tomatoes were affected by the plastic layers of HT and plastic mulch. These quality attributes also varied from year to year.

- In year 2021, the pH of both varieties was slightly affected by plastic cover and plastic mulch; double-layer plastic cover decreased total titratible acidity (TTA) of both cultivars grown on the bare soil, but increased TTA of fruits grown under mulched soil; total soluble solid (TSS) of tomatoes grown on bare soil under double-layer high tunnel were higher than those on under single-layer high tunnel, but the effect of layers of plastic cover on the tomatoes grown on mulched soil varied with cultivars; total lycopene and vitamin C content of tomatoes grown in single-layer high tunnels were significantly higher than those in double-layer high tunnel regardless of cultivars and mulching.

- In year 2022, the pH of Brandywine fruit was not affected by plastic cover and plastic mulch; the pH of Rebelski fruit was only slightly affected by plastic mulch; the TTA of tomatoes grown on bare soil under double-layer high tunnel were significantly lower for both varieties but higher for those grown on mulched soil compared to tomatoes grown in single-layer high tunnels; lycopene and vitamin C content of tomatoes grown in single-layer high tunnels were significantly higher than those in double-layer high tunnel regardless of cultivars and mulching.

- The correlation between redness and lycopene of tomato fruit was negligible for Brandywine, and slightly positive for Rebelski in 2021. However, this correlation was moderately positive for Brandywine tomatoes, but negligible for Rebelski tomatoes in 2022.

Objective 3: The enterprise budgets and cost benefit analyses were finalized in October 2022. The enterprise budget analysis included single-layer and double-layer high tunnels producing organic and conventional varieties of tomatoes based on the 2021 and 2022 production cycles. In 2021 single-layer enterprise budgets for organic tomatoes illustrate positive income above variable costs, excluding labor costs, as well as positive income above all costs. However, single-layer conventional high tunnel did not return positive income above all costs. Likewise, double-layer enterprise budgets for organic tomatoes returned positive income above all costs; whereas, the conventional tunnelfailed to show positive returns when factoring in the labor costs.

- The cost-benefit analyses included the net present value (NPV), the internal rate of return (IRR), and the payback period (PBP) methods. Single-layer organic tomatoes were acceptable investments using the NPV [$14,734.59 and $22,774.50, respectively] assuming a 10-year planning horizon and a discount rate of 8%. The IRR and PBP for the two double-layer high tunnels were both acceptable at 21-35% and 4 years, respectively. The implication of these results reveal that both tunnels with organic varieties will pay themselves back in 4 years based on their estimated cash flows discounted over the 10-year planning horizon. Unfortunately, conventional high tunnels did not return as positively as organic high tunnes. Conventional tunnel with single-layer cover showed a NPV of $1,249.42. Although acceptable, the return is assumed over the 10-year planning period, which is returning on average $124.94 each year. In addition, the IRR and PBP were 10% and 6 years, respectively, which are considerably lower than organic returns.

- 2021 double-layer organic high tunnel tomatoes were acceptable for all analyses. However, double-layer conventional high tunnel tomatoes was unacceptable for with an NPV of -$1,180.16, IRR of 6%, and PBP of 8 years.

- The same process was utilized for the 2022 harvest; however, due to extenuating circumstances, the data were not fully incorporated into the research. Many of the expenses remained the same apart from seed prices and labor. It is important to note that in 2022, the marketable yields were significantly lower than than the previous year, with many of the tunnels not generating a total receipt above $5,000. All single-layer tunnels (organic and conventional) should be rejected, with the exception of one organic tunnel NPV returning $1,024.80 ($102.48 on average per year) over the 10-year planning horizon. All double-layer tunnels were rejected for 2022.

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 and field demonstrations showcased different types of high tunnels and tomato cultivars. They will increase their knowledge in high tunnel specialty crops, especially tomato that is the No. 1 high tunnel crop, production. They will make informed decisions if a high tunnel should be included in their farm operation, and if so, they will be able to decide if one layer or two layers of plastic film should be used after learning the pros and cons of having the second layer of plastic cover. Altogether, small farmers using high tunnels will see increased yield and produce quality, expanded production and market season, and ultimately make more profits from farming and improve their quality of life.

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.

Project findings will greatly contribute season extension knowledge and practices for high yield and quality vegetable crops in the Southeastern US. Our project will answer a fundamental question in high tunnel production - layers of plastic covers on high tunnels.

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

Tomatoes are one of the most important, nutritive and flavorful vegetable crops. They are rich in lipid soluble and water soluble antioxidants such as lycopene and vitamin C; they also contain a 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 vegetable crops 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.

There were no major chanlenges encounter this year.

Results were disseminated through field days, extension publications, and conference/workshop presentations.

We will focus on in-depth data analyses and preparing extension and research publications in the next reporting period.

Sustainable Solutions to Problems Affecting Bee Health

Project Director

David Tarpy

Organization

North Carolina State University

Accession Number

1020447

Annual Result Sustainable Solutions to Problems Affecting Bee Health

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

(1) To evaluate the role, causative mechanisms, and interaction effects of biotic stressors (i.e. parasitic mites, pests, and pathogens) and abiotic stressors ((i.e. exposure to pesticides, poor habitat and nutrition, management practices) on the survival, health and productivity of honey bee colonies as well as within pollinator communities.
(2) To facilitate the development of honey bee stock selection, maintenance and production programs that promote genetic diversity and incorporate traits conferring resistance to parasites and pathogens.
(3) To develop and recommend "best practices" for beekeepers, growers, land managers and homeowners to promote health of honey bees and pollinator 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.

We have demonstrated that commercial queens mate with an adequate number of drones and store an expected number of sperm. Preliminary data also suggests that there is a well-established feral population of honey bees with significant levels of genetic diversity. Finally, we have established several links of colony genetic diversity--as a consequence of the queen mating multiply--to colony health (e.g., disease prevalence) and productivity (e.g., worker population). A focus on honey bee queens is a priority for apiculture research, as surveys of beekeepers self-identify problems associated with queens. Determining that commercial queens are adequately mated rules that factor out as a major determinant of colony ill-health, which therefore enables us to focus on other, less-direct factors associated with queen problems. This will enable us to bolster colony productivity and minimize colony loss in a tangible manner.
Our dataset of honey bee viruses is also the largest ever generated, which enables us to find important associations between viral presence and intensity with various measures of colony health. This will be important to identify and address best management practices that reduce or mitigate total viral loads among colonies bolstering the health of the honey bee population.

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

Beekeepers, especially queen producers, have been able to better quantify the reproductive quality of their queens through our Queen & Disease Clinic, which helps not only their own operations but also those of their customers. In doing so, it has addressed some of the systemic issues of queen problems within the industry and beekeeping community.

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

With a more reliable managed honey bee population, the pollination services that they provide help to support approximately one-third of our daily food supply especially the healthy fruits, vegetables, and nuts that comprise a healthy diet.

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.

DELIVERED TRAINING, DATA, AND RESEARCH TO SUPPORT HONEY BEE HEALTH AND PRODUCTIVITY: Honey bees play a critical role in agriculture, providing pollination to support approximately one third of our daily food supply, especially the fruits, vegetables, and nuts included in a healthy diet. To protect honey bee populations, NC State researchers are evaluating how various stressors—such as pests, diseases, pesticide exposure, and other environmental factors—affect the survival, health, and productivity of honey bee colonies and pollinator communities. They are also facilitating the development of honey bee stock selection, maintenance, and production programs that promote genetic diversity and pest and disease resistance. Notably, they have addressed systemic problems with honey bee queen health by teaching beekeepers, especially queen producers, to better measure and enhance the reproductive quality of their queens through the Queen & Disease Clinic, generated the largest dataset of honey bee viruses to date to improve identification and management of viral disease in colonies, and provided new insights into commercial queen breeding and the effects of genetic diversity on colony health and productivity.

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

x

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.

x

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

x

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

x

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.

x

Understanding how symbiotic fungi affect plant productivity and stress resilience across scales

Project Director
Christine Hawkes
Organization
North Carolina State University
Accession Number
1018688

Annual Result: Understanding how symbiotic fungi affect plant productivity and stress resilience across scales

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

The plant microbiome can change how plants grow, access nutrients, and tolerate stress. As stressors such as drought and pathogens continue to significantly reduce crop yields and the cost of inorganic fertilizers continues to increase, the microbiome provides an alternative approach to sustainable 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, time, and crop species. To that end, we study the fungi living inside plants, which we have demonstrated have large impacts on host physiology, stress tolerance, nutrition, 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.

In the past year, we made significant progress toward understanding the ecology of plant-fungal interactions and their underlying mechanisms using field sampling of common gardens, controlled microcosm experiments, and experimental field inoculations. Microcosm studies enable us to isolate effects of specific symbionts or consortia, while field studies in natural and agricultural ecosystems facilitate studies of fungal community assembly and function in real-world conditions. More specifically, in the past year we used a combination of these approaches to (1) analyze bacterial microbiomes associated with switchgrass leaves, roots, and soil at 14 sites across NC, (2) characterize foliar fungi associated with four wheat cultivars and

surrounding vegetation in seven common gardens across NC both early and late in the growing season, (3) test how foliar endophytes affect pathogen resistance in wheat and corn, (4) examine how root endophytes affect switchgrass access to organic nutrients.

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

Microbial community assembly on switchgrass

One of the existing controversies in community assembly of plant microbiomes is whether local soils are the primary reservoir of taxa that colonize plant roots and leaves. In previous work with switchgrass across a drought gradient, we used source-sink analysis to demonstrate that plant-to-plant transfer was the most common route for colonization for individual plants growing in native grasslands. Here, we expanded this work to 14 large stands of switchgrass planted for biofuels and forage across NC. We used network analysis to demonstrate that leaf and root bacteria are not nested subsets of soil bacteria, but instead depend on local environmental filters. **This contradicts studies from single sites, and suggests that our future management of crop microbiomes will require significantly better knowledge of local and regional source pools.** Our previous work (manuscript in review) supports this need, as nearby unmanaged vegetation was a robust predictor of both crop microbiome community structure and heterogeneity.

Understanding the wheat microbiome

To further understand agricultural microbiome community assembly, we focused on wheat. Sampling took place in 2022 at 7 common garden sites across NC, where four wheat cultivars were planted in a randomized block design. We sampled the foliar microbiome at four dates (Dec, Mar, Apr, May) to capture the full growing season. In addition, to address potential sources of wheat fungi, we also extensively sampled soils and the nearest non-crop plants (woody and herbaceous) in the surrounding landscape at two dates (Mar, Apr). Finally, to examine early and late whole-plant microbiomes, we sampled roots and soils (Dec, May). We will characterize the overall fungal and bacterial community patterns based on Illumina sequencing. We also isolated ~13,000 fungal strains and ~1,000 bacterial strains from the samples. Based on Sanger sequencing of ~4,000 fungal, we have representatives from ~80 fungal genera and 28 bacterial genera. A subset of fungal strains will be chosen for whole-genome sequencing, which will allow us to apply population genomic methods to better understand fungal migration patterns among hosts. **We expect results of this extensive sampling effort to shed light on how communities assemble in wheat, and what that means for potential future management of the wheat microbiome.**

Foliar fungal endophyte effects on pathogen resistance in corn and wheat

We used two experiments to understand how fungal endophytes can change crop disease resistance. Fungi were originally isolated from corn, wheat, and switchgrass, and we selected subsets for further study based on a range of inhibition in culture against either southern corn leaf blight (SLB; *Bipolaris maydis*) or Septoria nodorum blotch of wheat (SNB; *Phaeosphaeria nodorum*). To test the effect of endophytic fungi on wheat disease resistance, we grew a susceptible cultivar of wheat in controlled, gnotobiotic microcosms with ten fungal strains with or without the SNB pathogen. Plants were scored for disease symptoms and then leaves were either flash-frozen for later analysis of gene expression or placed in ethanol for staining and microscopic analysis of colonization. Results of this work will be compared to a field study where we sampled four wheat cultivars in a common garden with and without SNB to detect natural patterns of endophytes and plant gene expression responses associated with disease. In the second experiment, we inoculated a susceptible cultivar of corn grown at a single site with 21 different foliar endophytic fungi in a randomized block design. After 1 week, the entire field was then inoculated with the SLB pathogen. Disease symptoms were scored weekly. At the harvest, we measured plant size and froze corn leaves for later fungal community characterization. Initial analyses of disease scores indicate differences across the fungal inoculation treatments. We are currently preparing samples for Illumina sequencing. **By testing a large number of fungal endophytes, these experiments go beyond studies of single strains to help plant scientists, microbiologists, and plant pathologists to understand the broad potential for fungal endophytes to affect plant disease resistance.**

Examining the role of root endophytes in switchgrass access to soil nutrients

Organic fertilizers (e.g., animal manure) are low-cost alternatives to expensive inorganic fertilizers, but plants cannot directly access organic nutrients – these must be broken down by microbes into available forms. In 2021, we tested how 40 root endophytic fungi (Ascomycetes) affected switchgrass access to organic sources of nitrogen (N) and phosphorus (P). We

subsequently analyzed plant tissue nutrient content and found that 20% of the fungi (n=8) more than doubled plant tissue N and 30% (n=12) of fungi could increase tissue N by 20-90% above fungus-free controls and up to 10 times higher than from inorganic sources. Similarly, 40% of RAA-fungi (n=16) increased tissue P by 25-80% compared to fungus-free controls, and up to double that from inorganic sources. Most importantly, some fungi could shift the ratio of N-to-P, which ranged from 22 times more N than P to nearly equal amounts of N and P. The increased overall uptake and N-to-P decoupling suggests that the fungi have differential access that can be exploited to target both N limitation and P offtake. We are currently using microscopy to determine how each fungus colonizes the root. Fungi on the root surface are likely making nutrients more available in the rhizosphere, whereas fungi that can colonize the interior of the root (and particularly enter inside cells) may be involved in direct transfer of nutrients to the plant. A subset of fungi will be chosen based on these results to test in a split-pot experiment with 15N-labeled leaf litter as the only source of N and P to understand the potential for trade between the host and the fungus. **Ultimately, the results of this work may provide a new biological target for improving plant nutrition in agriculture.**

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

With increasing prevalence of extreme drought and high temperatures, there is a critical need for the development of new tools to improve crop stress tolerance. 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

In the past year, ten undergraduate students received training as part of this work, including eight women and two student from underrepresented groups. Each student was trained in a variety of methods ranging from fungal culturing to DNA extractions to seed sterilization. In addition, one student carried out an independent project assessing how root endophytes access soil iron. Graduate students Rachel Hammer, Xavious Allen, and Harry Ervin also were trained in experimental design, setup, and harvest, fungal substrate assays, and Illumina library preparation.

Publications

In review:

Aimone C, Giauque H, **Hawkes** CV. Fungal symbionts that generate water-saver and water-spender plant drought strategies have diverse effects on host gene expression. Phytobiomes J

Whitaker BK, Heiniger R, **Hawkes** CV. Foliar fungal communities depend on crop identity and neighboring vegetation in agroecosystems. FEMS Microbiology Ecology

de Vries F, Lau J, **Hawkes** CV, Semchenko M. Plant-soil feedback under drought: history shapes the future. TREE

Published:

Heckman RW, Rueda A, Bonnette JE, Aspinwall MJ, Khasinova A, **Hawkes** CV, Juenger TE, Fay PA (2023) Legacies of precipitation influence primary production in *Panicum virgatum.* Oecologia 201: 269-278. doi: 10.1007/s00442-022-05281-x

Sandy MS, Bui T, Segura-Aba K, Ruiz N, Paszalek J, Connor EW, **Hawkes** CV (2022) Plant host traits mediated by foliar fungal endophytes and secondary metabolites. Microbial Ecology doi: 10.1007/s00248-022-02057-x

Evans S, Allison S, **Hawkes** CV (2022) Microbes, memory, and moisture: predicting microbial moisture responses and their impact on carbon cycling. Functional Ecology 36: 1430-1441. doi: 10.1111/1365-2435.14034

Whitaker B, Giauque H, Timmerman C, Birk N, **Hawkes** CV (2022) Local plants, not soils, are the primary source of foliar fungal community assembly in a C4 grass. Microbial Ecology 84: 122-130. doi: 10.1007/s00248-021-01836-2

Presentations

In 2022, Hawkes gave the invited John Karling Annual Lecture at the Mycological Society of America meeting in Gainesville, FL, as well as departmental seminars at University of Pennsylvania and UC Davis on the topic of how fungal symbionts mediate plant phenotypes.

Other products

We added approximately 14,000 strains of fungi and bacteria to our living culture library. These strains can be accessed in the future for functional tests, comparative genomics, and so forth. We also submitted raw sequence data to the NCBI Sequence Read Archive for plant gene expression responding to foliar endophytes in drought (PRJNA777108) and for corn, soy, wheat, and switchgrass foliar microbiomes (PRJNA845782).

Plans for 2023-24

We will carry out several new and ongoing experiments in the coming year. First, we will address how higher order interactions of endophytic fungal communities can be predicted by studying consortia of root endophytes on switchgrass and foliar endophytes on wheat. Second, we will address the mechanisms underlying nutritional benefits of root endophytes by testing carbon-nitrogen trade in a split-pot system. Third, we will continue our work on the wheat microbiome, to identify population genetic patterns of their fungal endophytes. Fourth, we will complete analyses for both plant gene expression and fungal community composition associated with from field and microcosm experiments on how endophytic fungi alter host disease resistance. Finally, we will submit manuscripts reporting on completed experiments including the distribution of switchgrass leaf, root, and soil bacteria, the effects of root endophytes on switchgrass access to organic nutrients, and the associations of foliar fungi with growth and yield traits in corn, wheat, and switchgrass.

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.

DELIVERED KEY INSIGHTS INTO HOW BACTERIA AND FUNGI AFFECT PLANT HEALTH: The plant microbiome is the community of microorganisms that live in and on plants. This microbiome is critical to preserving the productivity and safety of the agricultural food supply because it can change how plants grow, access nutrients, and tolerate stress. As stressors such as drought and disease continue to reduce crop yields and fertilizer costs rise, the microbiome can provide alternative approaches to sustainable agricultural management. NC State researchers have analyzed microbiomes associated with switchgrass leaves, roots, and soil across the state to determine why they occur where they do; characterized fungi associated with four wheat cultivars and surrounding vegetation to identify sources of the wheat microbiome; tested how microorganisms living inside plant leaves affect disease resistance in wheat and corn; and examined how microorganisms living inside plant roots affect switchgrass crops' access to organic nutrients. To date, they have identified key environmental and biological controllers of microbiome community assembly at the local and regional levels, and they are beginning to identify the mechanisms that determine how fungi interact with plants to affect stress and disease resistance. They have also suggested new potential avenues for improving plant nutrition in agriculture without increasing the use of commercial fertilizers. Overall, their findings suggest several novel strategies for improved management of agricultural ecosystems via plant and soil microbiomes. This research has been shared through student training, in peer-reviewed publications, and in academic presentations. By laying the groundwork for new, sustainable approaches to crop management, this research will support a more affordable, secure, and productive food supply.

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

x

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.

x

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

x

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

x

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.

x

EVALUATION OF LAYING HEN PERFORMANCE, WELFARE, ECONOMIC RETURN, AND EGG QUALITY AND SAFETY FOR SUSTAINABILITY AND MAXIMIZATION OF RETURNS

Project Director
Kenneth Anderson
Organization
North Carolina State University
Accession Number
1016054

Results for Project Period 10/1/2021 - 9/30/2022

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

There are 3 issues which have driven my program. First, is the HPAI outbreaks the first in 2015 and the current one which has been going throughout 2022. The major component for my contribution in this area has been associated with the Mass Depopulation of laying hens, broilers and turkey which need to be killed to prevent further spreading of the disease. Second, is the increase in the public awareness of sustainability and the impact that the poultry industry is having on the carbon footprint of the industry and looking at ways to mitigate this impact. Third, is the shift from cage to cage-free production and the implications this has for the industry associated with production and product safety.

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.

Urgent circumstances affecting animal production starting in 2015 through today has led to the evaluation of methods to depopulate large numbers of animals as quickly as possible. The depopulation methods currently existing, need to be available when circumstances dictate their use. The more controversial methods to depopulate animals are related to ventilation shutdown (VSD). However, one must keep in mind that all the depopulation methods utilize VSD during the implementation processes. It is important to understand how these methods work quickly on the physiology of the birds to cause death. Anoxia and Hypoxia appear to cause death, however another contributing factor is the disruption of the acid-base balance in the body, disrupting homeostasis. Hypothermia and Hyperthermia, have been observed depending on the method of depopulation. Laying hens, broilers, broiler breeders and turkeys react differently, further highlighting that there is no single method of depopulation universally acceptable. Season, house design, management system, bird age, availability of resources, worker safety, and training contribute to selection of the method used. The EEGs of layers show they go unconscious very quickly whereas Turkey's EEG indicates a level of consciousness throughout the process regardless of the method. Broilers and broiler breeders are intermediate in their EEG responses. There is a point where hyperthermia becomes the determining factor in death. We have found that all birds have a surprising resistance to Hyperthermia up to the point of

exhaustion which occurs rapidly during the final 10 minutes of the process at a core body temperature ranging from 112°F to 117°F depending on bird size, temperature, humidity and access to resources. VSD+ does meet the depopulation criteria put forth in the "Red Book" and though distasteful, the process has been refined to make it faster which is the only criteria that indicates it is better.

During this time of technological advancement and shifting agricultural practices, the human population continues to grow due to the numerous benefits these advancements provide such as access to a safe and continuous food supply. Efficient farming techniques improve the nutritional health of the population, however, as the population continues to grow, so does the demand for high protein food, which comes at an environmental cost. Carbon dioxide (CO2) makes up 65% of the global greenhouse gas emissions (GHG), with approximately 21-37% of those emissions coming from the global food system alone. CO2 acts as insulation around the Earth, trapping heat that would otherwise be emitted into space in the Earth's atmosphere. As the predominant GHG in the atmosphere, CO2 is responsible for the majority of global warming, and its increasing concentrations is causing worldwide concern. The average global temperature has increased at a rate of ~0.18°C per decade since 1981, approximately double the decennial rate since 1880 (~0.08°C) (3). The years of 2013-2021 account for nine of the ten hottest years globally on record (3), which explains the increasing push towards environmental sustainability and industrial accountability for carbon footprints. A carbon footprint is a collective summary of how much CO2, and other carbon compounds, is emitted by a person, company, etc. Because of the massive carbon footprint of the agriculture sector, and the increasing awareness of global warming, companies are beginning to take measures to decrease their carbon footprint. These companies, are implementing a unique strategy to help fight not only climate change, but one of the largest sole contributors to GHG emissions: food waste. On average, one third of the food produced globally for human consumption is not consumed, meaning that the resources, energy, and CO2 emissions used to produce that third is wasted as well. Global food waste and loss accounts for approximately 8% of anthropogenic GHG emissions, nearly equal to the amount attributed to transportation. Emissions of food waste are so high, that if food waste was a country, it would rank number three in top GHG emitting countries in the world. Large sources of emissions included in total food waste emissions are emissions from landfills, water, and land use. In the US alone, uneaten food is the most abundant material in landfills (24% of total input), consumes 14% of all fresh water use, and uses 18% of available crop land to grow. One way to combat food waste emissions is by taking food waste from grocery stores and converting it into chicken feed. In the livestock industry, the production of animal feed is the second largest contributor to GHG emissions, with feed production making up almost half (49.4%) of the total CO2 emissions. The poultry egg production industry alone emits around 2-4 kg CO2 equivalents per kg of eggs depending on the rearing method. In 2009 the US produced over 5.3 million tons of eggs with Iowa, the top egg producing state in the US, emitting a weighted average of 5020 kg of CO2 per ton of eggs produced, again, with feed production making up the majority (around 82%) of those emissions.

The transition to cage free is a major problem and the speed of the transition continues transform change in the egg industry negatively in its path towards extensive production systems to meet the desire of consumers. These changes do not improve welfare or safety of food produced by the birds in production systems which are perceived as more humane. The problem is the separation the consumer has from production agriculture and does not understand the inherent issues associated with poultry production in general and the added costs they will have to pay for eggs produced in these systems. Initial estimates indicate that consumers in California have paid more than $1.25 billion in added food costs. In addition, research has shown that the risks to the animal health and welfare in more extensive systems is worse. Indicating the need for more opportunities for training and professional development, which this project has provided.

The North Carolina Layer Performance and Management Program has been on hold since COVID. The goal is to restart the program post COVID so the NCLP&MT continue to provide performance data to the industry in the years to come in cooperation with the NC Department of Agriculture and Consumer Services and the Primary Breeders of Commercial Egg Strains. The NCLP&MT was designed to examine the strain by production system performance in an unbiased manner for egg producers in North Carolina and throughout the world. The test provided insight to egg companies to understand potential problems related to the management of the different genetic strains of white and brown egg layers that they may experience. These strains are commercially available in production systems used in the US. The 41st NCLPMT is being planned to start again in 2023.

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

The research we have been working on has been focusing three issues confronting the egg industry today. First, is the shift of egg production from primarily intensive production in cages to cage-free which is extensive production. We do not understand what these shifts in production systems will have on egg production and quality. Increasing the understanding of these impacts on egg production and quality will help the primary breeders evaluate their selection strategies and the producers how to enhance or modify their management to improve production and subsequent egg quality. Second, is the utilization of

alternative feed ingredients to replace conventional protein and energy sources such as Soybean meal or Corn. By recapturing nutrients which would be destined for the landfill we can significantly reduce the carbon footprint of production. Third, with the2015 HPAI and the current HPAI outbreak in the poultry industry the research we have done related to depopulation of laying hens, broilers, broiler breeders, and turkeys has provided the industry and USDA-APHIS a set of tools that can be used in the depopulation of diseased flocks. The VSD+ process developed has been used extensively in 2022 by incident commanders from APHIS

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

Nothing to 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.

DELIVERED TOOLS AND INSIGHTS TO ENHANCE POULTRY PRODUCTION SUSTAINABILITY, PROFITABILITY, AND SAFETY: Outbreaks of highly pathogenic avian influenza (HPAI), the increase in consumer demand for sustainably produced eggs and egg products, and the shift from cage to cage-free poultry production have created new challenges for the industry. To address these issues, NC State researchers have studied methods for rapidly and humanely depopulating diseased poultry flocks and have provided new tools, including an improved ventilation shutdown process that more rapidly depopulates diseased flocks, leading to reduced flock distress. This process has been shared with industry and used extensively by USDA-APHIS incident commanders in 2022 to control the most recent HPAI outbreak. Researchers have also provided data-driven insights for enhancing professional training for poultry producers to improve flock health and welfare, and they are working to understand the impact of cage-free production on egg production and quality, with a focus on helping breeders evaluate their selection strategies and helping producers enhance or modify their approaches. They have also advanced knowledge of methods for recapturing nutrients previously destined for the landfill and repurposing them as alternative feed ingredients to significantly reduce the carbon footprint of poultry production.

delete

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

x

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.

x

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

x

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

x

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.

x

Genomic and Proteomic Breeding in Cultivated Virginia-type Peanut

Project Director

Jeffrey Dunne
Organization
North Carolina State University
Accession Number
1016934

Annual Result: Genomic and Proteomic Breeding in Cultivated Virginia-type Peanut

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

The long-term objective of this research is to develop a high-throughput genotyping pipeline specifically for the improvement of Virginia-type peanut cultivars for the Virginia-Carolinas (VC) production region. Antecedently, this requires improved marker discovery in Virginia-type peanuts and development of a genotyping approach that is both efficient and economical. A use case involving high throughput genotyping and intensive phenotyping to develop marker-trait associations in cultivated and wild species for resistance to leaf spot; a persistent, devastating fungal disease throughout the entire United States peanut producing region. Once established, this pipeline will be easily amenable to any market type or trait of interest in peanut, specifically for the mapping and selection of lines discussed in the project overview. Furthermore, on a per sample basis, genotyping costs will be reduced ~75% compared to the only currently available alternative. This will allow a breeding program to break even on genotyping costs after 2,850 samples, which is realistically reached by a single public sector plant breeding program within four years.

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 completion of the Bailey II genome assembly provided a Virginia-type specific reference for improved short-read sequencing alignments and efficient marker calling among germplasm and breeding materials in the North Carolina State University (NCSU) peanut breeding and genetics program. Using the Bailey II genome, whole-genome sequencing of peanut lines selected to represent a large portion of the genetic diversity present in Virginia-type peanuts were aligned for single nucleotide polymorphism (SNP) calling. Using a custom bioinformatics pipeline, 14,523 high-quality markers evenly spaced across the genome were identified for use in the peanut breeding program. These SNPs will be used in Tecan Allegro amplicon-based sequencing library construction recover the high-quality SNPs for Quantitative Trait Loci (QTL) mapping. This work was recently submitted as an original research manuscript for publication.

Newman, C.S., Andres, R.J., Youngblood, R.C., Campbell, J.D., Simpson, S.A., Cannon, S.B., Scheffler, B.E., Oakley, A.T., Hulse-Kemp, A.M. and Dunne, J.C., 2022. Initiation of genomics-assisted breeding in Virginia-type peanuts through the generation of a de novo reference genome and informative markers. *Frontiers in Plant Science*, *13*.

In 2021 and 2022, 265 lines, including novel breeding lines and germplasm material coming through the breeding pipeline, were grown at the Peanut Belt Research Station (Lewiston-Woodville, NC) and the Upper Coastal Plains Research Station (Rocky Mount, NC) for the characterization of leaf spot pressure and differentiation in the resistance among genotypes. In both years, plots were visually rated routinely by the peanut breeder using the Florida Scale (1-9), leaf tissue from each plot was evaluated for percent leaf spot lesions and drone images were captured to estimate percent defoliation. The purpose was to correlate the visual ratings to the weighted, visual evaluation on percent leaf spot lesions and defoliation. In addition to high-resolution DJI Zenmuse P1 camera, plots were imaged using a Micasense RedEdge Dual Multi-Spectral camera for a more high-throughput approach. Data is currently being compiled across both years and locations for mapping quantitative trait loci (QTL) for improved leaf spot resistance among the 265 breeding lines.

Each of the 265 advanced breeding lines evaluated in the leaf spot trials from 2020-2022 were sequenced using the Tecan Allegro targeted-amplicon sequencing platform for the 14,523 markers determined to be high-quality SNPs stemming from the preliminary marker development. The constructed libraries were sequenced using an Illumina NovaSeq 6000 SP 100bp SR flow cell. The data resulting from the sequencing is currently being aligned to the Bailey II reference genome to recover the markers used in identifying QTL through genome-wide association analysis.

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

First, the success of an individual cultivar that would come from the efforts during this project, in the seed market is a function of its appeal to seedsmen, growers, shellers, and processors of peanuts. New cultivars often are developed and released in response to the occurrence of new diseases or insect pests, or to address shortcomings of earlier releases as communicated to the breeder by the concerned parties. The breeder must collect extensive performance and quality data on candidates for

release, but it is the first year or two a new cultivar is in the hands of the seedsmen that are critical. Being producers themselves, seedsmen must be satisfied as to the agronomic performance of new cultivars before they will risk putting their resources into producing large amounts of seed. As a new release progresses through the seed chain (breeder, foundation, registered, and certified seed production), the seedsmen look at it critically in comparison to the relatively small number of cultivars with which it will compete, often with an eye toward subtle traits that the breeder may have overlooked. Because the seed must be shelled, shellers also get an early look at new releases in shelling plants during this time. The short lifetimes of several released cultivars in the seed market reflect shortcomings that became evident only when they reach the hands of growers and shellers in quantity. In addition to these groups, there are interested parties in peanut cultivars release from this program or based on the efforts from this project.

The American Peanut Council (APC) represents peanut stakeholders across the entire United States peanut industry. APC supports the long-term growth of the US peanut industry and, as part of its mission, releases initiatives that it determines are most relevant to the peanut stakeholders. The Peanut Foundation (TPF), as the research arm of APC, has recently announced Phase II of the Peanut Genome Initiative (PGI). PGI has determined that the main priority “research target area” is disease resistance, focused on leaf spot. According to TPF, leaf spot has been assessed to cause $53 million in losses annually for American peanut producers.

Leaf spot is the primary concern of stakeholders because it occurs in all peanut producing regions, and currently, producers rely on fungicide treatments, primarily to combat early (*Passalora arachidicola*, formerly *Cercospora arachidicola*) and late (*Nothopassalora personata*, formerly *Cercospora personatum*) leaf spot. In the VC region alone, peanut farmers spend ~$80/acre2, or $17 million annually, on fungicide treatments. These pathogens are rapidly overcoming both host resistance and chemical treatments throughout the entire peanut producing region of the United States. Furthermore, there seems to be a limitation on novel chemistries and more of an emphasis on combination fungicides, which has the potential of allowing the pathogens to develop resistance to multiple fungicide modes of action. Therefore, peanut farmers throughout the region and nation would benefit immensely from varieties that show even moderate-to-high levels of resistance.

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

Downstream users of peanuts would benefit from a stable supply of high-quality products. Simultaneously utilizing fewer pesticide applications would reduce the ecological footprint of peanut farming, producing peanuts in a more economically sustainable manner.

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 - The preliminary results of each objective have been reported/presented at the American Peanut Research and Education (APRES) Society meetings in 2021, at professional field day events at the NCDA research farms (PBRS; Lewiston-Woodville, NC; UCPRS; Rocky Mount, NC; BBTRS; Whiteville, NC) and the farms associated with Virginia Tech (TAREC; Suffolk, VA), and through peanut advisory (Virginia-Carolina) and grower's association meetings (VA, NC and SC).

Dissemination of Information - Newman, C.S., Andres, R.J., Youngblood, R.C., Campbell, J.D., Simpson, S.A., Cannon, S.B., Scheffler, B.E., Oakley, A.T., Hulse-Kemp, A.M. and Dunne, J.C., 2022. Initiation of genomics-assisted breeding in Virginia-type peanuts through the generation of a de novo reference genome and informative markers. *Frontiers in Plant Science*, *13*.

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.

DEVELOPED NEW CULTIVARS AND GENOTYPING APPROACHES FOR DISEASE RESISTANCE IN PEANUTS: Peanuts are an important source of edible oil and protein in over 100 countries. But peanut breeders face major challenges associated with a lack of genetic diversity that leaves peanut crops especially vulnerable to evolving pests and environmental changes. NC State researchers are using cutting-edge molecular breeding technology to create better tasting peanut varieties resistant to environmental stresses like drought and disease. NC State has already released the highly successful Bailey and Bailey II varieties with built-in resistance to the highly damaging early leaf spot disease. They are currently developing an efficient pipeline for analyzing and improving peanut cultivars for the Virginia-Carolinas region. Once established, this pipeline will

make it easier for researchers to map and select beneficial breeding lines, and it will reduce genotyping costs by an estimated 75% compared to the currently available alternative method. They are also working to fortify the Bailey cultivar with genetic resistance to late leaf spot, a common, fast-moving disease that costs growers an estimated $53 million annually.

DELETE

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

x

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.

x

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

x

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

x

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.

x

THE POPULATION GENOMICS OF MYCOTOXIN PRODUCTION AND DEVELOPING NEW BIODIVERSITY INFORMATICS TOOLS

Project Director
Ignazio Carbone
Organization
North Carolina State University
Accession Number
1017024

Annual Result: THE POPULATION GENOMICS OF MYCOTOXIN PRODUCTION AND DEVELOPING NEW BIODIVERSITY INFORMATICS TOOLS

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

Toxins produced by fungi (mycotoxins) are an enormous problem in agriculture, particularly the aflatoxins produced by *Aspergillus flavus*. The economic cost resulting from direct losses due to aflatoxins are estimated at $240 million annually in the United States alone. Using nonaflatoxigenic *A. flavus* strains as biological control agents to reduce aflatoxin concentrations in both seeds and grains has shown promise but much remains to be learned about these fungi in agricultural settings. The goal of this project is to examine the underlying genetic and genomic processes that result in population shifts favoring nonaflatoxigenic fungi. Specifically, we seek to integrate Next Generation Sequencing (NGS) data and phenotypic data across experimental and natural populations to characterize the interactions among biotic and abiotic components of agricultural ecosystems. This will lead to a better understanding of fungal adaptation, the genetic basis of sexual fertility in *Aspergillus,* and the impact that genome plasticity has in response to changing environmental and ecological pressures. This

knowledge will be important in developing more cost-effective and sustainable biocontrol strategies. In parallel, we are developing advanced bioinformatics tools to accelerate our understanding of the evolution of mycotoxicity and microbial biodiversity.

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 activities and outputs:

1) We used genotyping-by-sequencing to examine the influence of nonaflatoxigenic biocontrol agents (Afla-Guard, AF36) on native populations of *A. flavus* in cornfields in Texas, North Carolina, Arkansas, and Indiana. Population genetic analysis of 27,529 single-nucleotide polymorphisms (SNPs) in a total of 815 *A. flavus* isolates revealed increased unidirectional gene flow inferred to be due to the applied Afla-Guard biocontrol strain. Genetic exchange and recombination of biocontrol strains with native strains was detected in as little as three months after biocontrol application and up to one and three years later. These results will be used to develop new biocontrol strategies.

2) We implemented two new tools, SplitsTree and Hypha, in our online DeCIFR (https://decifr.cifr.ncsu.edu/) toolkit. These tools were used to examine patterns of reticulate evolution for 815 *A. flavus* isolates. We also deployed the Popgen Pipeline Platform (PPP) software in our DeCIFR suite to facilitate input file generation when using IMa3, a tool for modeling isolation with migration in our data. Collectively these tools will be used to track the movement of biological control strains released in the environment.

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

During this reporting period we published the Molo et al 2022 paper demonstrating asymmetrical lineage introgression and recombination in populations of *Aspergillus flavus*. This is the first reported evidence of biocontrol strains of *A. flavus* recombining with natural populations and the first to show that biocontrol strains derived from different evolutionary lineages (i.e., IB and IC) have different evolutionary trajectories in their interactions with native populations.

The tools in the DeCIFR toolkit were used by I.C for teaching an upper-level graduate course (PP715) in Fall 2021 focusing on applied evolutionary population genetics. The tools were also used for research and yielded 16 published papers during this reporting period.

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

Because lineage IB isolates are predominantly nonaflatoxigenic, populations with a greater proportion of lineage IB strains relative to lineage IC are predicted to have lower aflatoxin levels. This was shown in commercial cornfields in the Molo et al 2022 paper. This suggests that it might be possible to shift *A. flavus* populations to a state that is functionally and qualitatively similar to the native population but quantitatively have a much-reduced aflatoxin footprint than the native population. This has significant implications for reducing aflatoxin contamination in North Carolina and other regions where lineage IC predominates.

delete

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

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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.

x

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

x

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

x

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.

x

Turfgrass Breeding and Genetics

Project Director
Susana Milla-Lewis
Organization
North Carolina State University
Accession Number
1016714

Annual Result: Turfgrass Breeding and Genetics FY22

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

North Carolina is located in the transition zone for cool- and warm-season grasses. While this means that we can grow both types of grasses, no one type of grass does well in all weather conditions. Cool season grasses go dormant during hot, dry months and can turn brown and even die during extremely hot and dry conditions. Warm-season grasses have lower water requirements, which make them ideal during the summer months. However, they go dormant and turn brown during the cool days of fall and winter, and winterkill can often be a problem in the NC region.

Despite the fact that large amounts of genomic information have been generated for other grasses such as rice, maize, and wheat, turfgrass species have lagged far behind. Work is needed to generate such information and utilize it to relate phenotypic traits to DNA nucleotide polymorphism.

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.

Applied plant breeding can be used to develop turfgrass cultivars that are better adapted to environmental conditions present in North Carolina. Development of cool-season grasses with increased heat and drought tolerance, and warm-season grasses with improved cold tolerance would contribute significantly to different sectors of the turfgrass industry. Genetics and applied plant breeding can also be used to improve aesthetics, performance, and disease resistance of turfgrass cultivars which, in turn, affect the efficiency of maintenance and production. The long-term goal of the program is to improve the sustainability and economic gain of the overall turfgrass industry in the state through the development of cultivars that require reduced inputs and that are capable of tolerating biotic and environmental stresses while still maintaining good quality and overall performance. Additionally, the program is focusing on generating genomic information and utilizing it to relate phenotypic traits to DNA nucleotide polymorphism.

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

1. The turfgrass industry loses about $300M annually due to problems caused by insect and fungal pests, and environmental stresses such as drought, heat, shade, and cold (North Carolina Turfgrass survey, 1999). Through breeding and selection for abiotic and biotic stress tolerance in St. Augustine-, and zoysiagrass, improved breeding lines have been developed. One cultivar of each of these species have been released in the last two years. ‘Lobo’ zoysiagrass has improved drought tolerance, persistence under low inputs, and large patch resistance. ‘Sola’ St. Augustinegrass has improved drought tolerance, shade tolerance, and resistance to grey leaf spot and the southern chinch bug.

2. Development of new cultivars of turfgrass can require more than 12 years from the point of an initial cross to commercial release. Development of novel breeding techniques involving the application of DNA markers can dramatically lessen the time required for society to benefit from new and improved plant varieties. Our work in St. Augustinegrass and zoysiagrass genomics has made a significant contribution in advancing these methodologies for turfgrass. Molecular markers associated with traits of interest developed by our group are available to turfgrass geneticists and breeders in the U.S.A. and internationally to further the knowledge base in basic plant biology and also to increase selection efficiency.

3. Our work on molecular characterization of different warm-season grass has helped elucidate intra- and inter-specific relationships in these species. Our work on zoysiagrass resulted in the identification of true interspecific hybrids and provided crucial information to understanding speciation in the genus. In St. Augustinegrass, knowledge of ploidy levels and genetic relationships among Stenotaphrum germplasm generated by the program will allow for more efficient models for germplasm utilization in the genus. Our results have made a significant contribution to the strategic utilization of available germplasm in cultivar development.

4. Artificial polyploid lines have been produced through the use of colchicine in order to develop bridge genotypes for crosses between St. Augustinegrass and disease resistant accessions of pembagrass. Chromosome doubling was confirmed through the use of flow cytometry and cytological chromosome counts. These lines will facilitate transfer of useful traits from polyploidy relatives of St. Augustinegrass.

5. Recurrent selection has been used in tall fescue to develop populations with improved heat and drought tolerance. Tall fescue synthetic cultivars NC-1 (commercial name 'Tara') and NC-2020 (commercial name 'Heatwave') were developed jointly by North Carolina State University and Blue Moon Farms LLC. (Lebanon, OR) and released because of their improved for summer stress tolerance.

6. After initial evaluation of over 5,000 centipedegrass lines developed from our efforts in mutation breeding, 20 breeding lines have been selected based on their superior performance on establishment, turf quality, drought and cold tolerances, and seed yield. These lines were planted on sod farm trials in 2022 and are currently under evaluation in order to make a final decision on commercial release.

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

Grasses developed in this program will save consumers money from reduced water needs and a reduced need to renovate or replace grass following many climatic events that have traditionally damaged North Carolina's turfgrasses. This savings are due to the improved turfgrass genetics from this program resulting in increased drought resistance, cold tolerance and increased disease resistance across multiple turfgrass species. This program has also developed novel breeding technologies that can improve efficiency of other plant breeders across the US and internationally. Development of new vegetatively propagated cultivars of turfgrass can require more than 12 years from the point of an initial cross to commercial release. As the NC State Turfgrass Breeding and Genetics Program was established in 2009, the first commercial releases are coming out now. A zoysiagrass, Lobo™, was commercialized in 2021, and a St. Augustinegrass, Sola™, in 2022. At least one centipedegrass will be released next year.

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 OPPORTUNITIES

Master's and doctoral theses being directed:

1. **M. Carolina Escalona.** MS. Breeding for drought tolerance in St. Augustinegrass: combining genomics and high-throughout phenotyping. (Advisor, Crop and Soil Sciences Department, initiated Fall 2022)

2. **Kirtus P. Houting**. MS. Elucidating components of genetic resistance to large patch in zoysiagrass (Co-Advisor, Crop and Soil Sciences Department, initiated Fall 2020)

3. **Greta E. Rockstad**. MS. Integration of high-throughput phenotyping and genomics for drought tolerance breeding in St. Augustinegrass (Advisor, Crop and Soil Sciences Department, completed summer 2022)

4. **Susmita Gaire.** PhD. Elucidating genetic and physiological components of freezing tolerance in St. Augustinegrass (Advisor, Department of Crop and Soil Sciences, initiated Fall 2020)

5. **Esdras M. Carbajal.** PhD. Improving turfgrass quality and disease resistance through inter-ploidy breeding in warm-season grasses (Advisor, Department of Crop and Soil Sciences, initiated Fall 2019)

6. **Ashley Schonmaker**. PhD. Analysis and Computational Methods for Understanding Disease Resistance at the Genomic Level in Complex Plant Systems (Co-advisor, Bioinformatics Program, initiated Fall 2019)

Other Mentoring Activities:

- Mentored one post-doctoral researcher, Dr. Beatriz Gouveia, January – December 2022.

- Mentored undergraduate students in research:
    - Chloe Williams, freshman in Plant Biotechnology major, Crop and Soil Sciences (August 2022 – present)

    - Emma Simpson, Senior in Biochemistry (May-August 2022)

    - Madison Lawson, Sophomore in Horticultural Science (August 2021- May 2022)

- Mentored four short-term international research scholars:
    - Gabriela F. Dos Santos (Jul 2022 – Jun 2023), Universidade Estadual Paulista, Sao Paulo, Brasil

    - Luis Bardales (Jul 2022 – Nov 2022), Universidad Nacional Agraria, Olancho, Honduras

    - Sergio Fernandez (Universidad Nacional de Agricltura, Olancho, Honduras), Sep 2021- Aug 2022

    - Alejandra Quiñones (Sep 2021- Feb 2022), Universidad Peruana Cayetano Heredia, Lima, Peru

DISSEMINATION OF RESULTS

Research abstracts:

1. *Escalona, M.C., Yu, X. and **Milla-Lewis, S.R.** 2022. Transcriptomic changes in the roots of drought-tolerant and sensitive St. Augustinegrass [*Stenotaphrum secundatum* (Walt.) Kuntze] genoytpes exposed to drought stress. Proc. Amer. Soc. Agron. Intl. Ann. Mtg., Baltimore, MD. Nov 6-9.

2. *Rockstad, G.B., Austin, R., Gouveia, B.T., Carbajal, E.M., and **Milla-Lewis, S.R.** 2022. Assessing unmanned aerial vehicle-based imagery for breeding applications in St. Augustinegrass. Proc. Amer. Soc. Agron. Intl. Ann. Mtg., Baltimore, MD. Nov 6-9.

3. *Rockstad, G.B., de Siqueira Gesteira, G., Yu, X., Gouveia, B.T., and **Milla-Lewis, S.R.** 2022. Identification of QTL associated with drought resistance in St. Augustinegrass. Proc. Amer. Soc. Agron. Intl. Ann. Mtg., Baltimore, MD. Nov 6-9.

4. *Houting, K.P., Kerns, J.P., Miller, G.L., Schwartz, B.M., Patton, A.J., and **Milla-Lewis, S.R.** 2022. Gaining insights into the polygenic inheritance of large patch resistance in zoysiagrass. Proc. Amer. Soc. Agron. Intl. Ann. Mtg., Baltimore, MD. Nov 6-9.

5. *Houting, K.P., Kerns, J.P., Miller, G.L., Schwartz, B.M., Patton, A.J., and **Milla-Lewis, S.R.** 2022. Evaluation of a zoysiagrass mapping population for field performance and correlations with large patch resistance. Proc. Amer. Soc. Agron. Intl. Ann. Mtg., Baltimore, MD. Nov 6-9.

6. *Carbajal, E.M., van der Laat, R., Miller, G.L., Dunne, J.C., Schwartz, B.M., and **Milla-Lewis, S.R.** 2022. Evaluation of shade tolerance and genetic diversity in South African bermudagrass accessions. Proc. Amer. Soc. Agron. Intl. Ann. Mtg., Baltimore, MD. Nov 6-9.

7. **Milla-Lewis, S.R.**, Carbajal, E.M., Gouveia, B.T., Houting, K.P., van der Laat, R., and Miller, G.L. 2022. Evaluation of seeding versus sprigging for establishment of centipedegrass (Eromochloa ophiuroides) germplasm in North Carolina. Proc. Amer. Soc. Agron. Intl. Ann. Mtg., Baltimore, MD. Nov 6-9.

8. Zhang, J., Maleski, J., Schwartz, B.M., Raymer, P.L., Kenworthy, K.E., **Milla-Lewis, S.R.**, Chandra, A., and Wu, Y. 2022. Assessing turfgrass for drought resistance using unmanned aerial system-based remote sensing. Proc. Amer. Soc. Agron. Intl. Ann. Mtg., Baltimore, MD. Nov 6-9.

9. ‡Gouveia, B., Schwartz, B.M., Wu, Y., Kenworthy, K.E., Chandra, A., Raymer, P.L., Wherley, B., Moss, J.Q., Cox, K., Pirtle, T., Buhlman, J.L., Hejl, R., and **Milla-Lewis, S.R.** 2022. Four warm-season turfgrass species under irrigation restrictions. Proc. Amer. Soc. Agron. Intl. Ann. Mtg., Baltimore, MD. Nov 6-9.

10. ‡Yu, X., de Siqueira Gesteira, G., Schoomaker, A., and **Milla-Lewis, S.R.** 2021. Genetic resistance of gray leaf spot in St. Augustinegrass: QTL mapping and transcriptomics. Proc. Amer. Soc. Agron. Intl. Ann. Mtg., Baltimore, MD. Nov 6-9.

11. Xiang, M., Moss, J.Q., Yu, S., Wu, Y., **Milla-Lewis, S.R.**, and Jespersen, D. 2022. Minimum water requirements of warm-season turfgrass cultivars and experimental selections. Proc. Amer. Soc. Agron. Intl. Ann. Mtg., Baltimore, MD. Nov 6-9.

Invited presentations:

1. **Milla-Lewis, S.R.** and Miller, G.L. Zoysiagrass Lunch and Learn. NC Department of Transportation. Webinar. October 18th 2022.

2. **Milla-Lewis, S.R.** Establishing a breeding program (from scratch). National Association of Plant Breeders – Graduate Students Work Group. Virtual presentation. February 24th 2022.

3. **Milla-Lewis, S.R.** Lobo zoysiagrass and Sola St. Augustinegrass: New turfgrasses with improved stress tolerance for North Carolina. North Carolina Crop Improvement Association Annual Meeting. Raleigh, NC. January 28th 2022.

Extension/Outreach activities:

1. Speaker at the 2022 Turfgrass Field Day at the Lake Wheeler Turfgrass Field Lab, Raleigh, NC, August 10, 2022

2. Speaker at the Resource Conservation Workshop, Lake Wheeler Turfgrass Field Lab, three tours each of 20 high school 4-H students, June 27th, 2022.

3. Speaker at the Sandhills Turfgrass Regional Conference and Field Day at the Sandhills Research Station, Jackson Springs, NC, June, 16th 2022.

PROGRAM PLANS

- Continue recurrent phenotypic selection for heat and drought tolerance in tall fescue

- Continue population development and selection in zoysiagrass, St. Augustinegrass and centipedegrass to improve turf quality in combination with abiotic and biotic stress tolerance

- Continue work on marker development, linkage mapping, and QTL mapping to identify markers linked to traits of interest that can be subsequently used for marker-assisted selection

- Continue work on germplasm evaluation to identify potential parents for incorporating traits of interest into breeding populations

- Continue involvement in graduate education and mentoring activities

- Continue engagement with industry members and stakeholders to establish and maintain relevant program goals

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.

RELEASED NEW CULTIVARS AND PROVIDED RESEARCH INSIGHTS TO STRENGTHEN NC TURFGRASSES: Turfgrass plays an important economic role in several industries, providing ground cover for homes, roadsides, parks, commercial properties, sports fields, and more. North Carolina is located in the transition zone for cool- and warm-season grasses. Although this means that we can grow both types of grasses, no one type of grass does well in all weather conditions. In addition, the turfgrass industry loses about $300 million annually to pests and environmental stresses. To address these challenges, NC State researchers have developed new turfgrass varieties, including Lobo—a robust, groundbreaking cultivar suitable for use in lawns, roadsides, and golf courses that boasts both reduced water requirements and improved cold resistance—and Sola, an improvement on a long-standing variety produced earlier by NC State, which offers aggressive growth, shade and drought tolerance, better resistance to chinch bugs and gray leaf spot, and superior sod strength. In addition to releasing new grasses that save money for consumers and industry, NC State's turfgrass breeding program delivers data and insights that help turfgrass breeders and geneticists increase selection efficiency in the US and internationally.

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

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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.

x

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

x

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

x

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.

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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

The Importance of U.S. Food and Agricultural Trade in a New Global Market

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 new renegotiation of the North American Free Trade Agreement (NAFTA), now USMC create uncertainties with respect to their implications for U.S. agriculture. The U.S. decision to withdraw from the Paris Accord also 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.

Current global issues including the Covid-19 pandemic is having a detrimental impact on the lives of communities and economies. (USAID Country Development Strategies, 2020). In addition, increasing fertilizer prices, drought-like conditions in the Southern Hemisphere, limited trade due to Covid-19 pandemic and the Russian invasion of Ukraine have increased uncertainty in global markets (Schnitkey et al., 2022; Saefong, 2022). Elevated uncertainty raises options premia, increasing risk management costs for farmers, traders, and other market participants who participates in commodity and global value chains (GVGs) markets to hedge their risks (Goyal & Adjemian, 2021).

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. Three on government policies, and one on trade agreements.

Objective 1:

(1) *COVID-19 Induced Supply Chain Effects on U.S. Meat and Poultry Products Export*. SUR-VAR models were applied to the quarterly data of U.S. beef, pork, and poultry exports from 2010 to 2020 with Covid-19 quarters included as dummy variables. The price hikes and export shocks were more severe in the Covid-19 quarters with that of beef been the largest. Contributions of H2A Temporary Agricultural Workers in the U.S. Meat Livestock Industry: Immigrant workers make up 73% of U.S. agricultural industry with more than 65% in the animal slaughtering and processing industry, and more than 35% are foreign born. These populations were disproportionately impacted by the Covid-19 since they are considered essential workers. To analyze the impacts of labor shortages and how that in turn affects the supply chain, we estimate models of total labor demand, while also accounting for the contribution of migrant labor (H-2A workers) in ameliorating the farm labor shortages. The major finding is that more than half (56%) increase in agricultural labor supply comes from immigrants.

(2) *The Impacts of Covid-19 on the U.S. Meat Industry. A Price Transmission Analysis.* The effects of the COVID-19 pandemic and the price transmission from wholesale to retail in the three main meat industries was explored. To understand the spike in retail prices in the market, a Vector autoregressive model (VAR) were applied to monthly data on the wholesale and retail meat prices of beef, pork, and composite broilers from USDA-meat price spreads from 2018 to 2021. The contemporaneous retail price was regressed over the wholesale, and the lags 1 and 2 of all the three retail prices. The results reveal only contemporaneous retail price of beef was affected by its lag-1 and the wholesale prices while that for pork was only affected only by its lag 1 and that of beef, and no price transmission for poultry. Thus, beef price was severely impacted.

(3) *COVID-19 Induced Supply Chain Effects on U.S. Meat and Poultry Products Export.* The COVID- 19 pandemic took a toll on the global economy, causing considerable disruptions in all spheres of the global market, especially food and commodity markets. Two forces that may have contributed to the price spikes in meat and meat products witnessed during the COVID pandemic are supply chain issues causing shortages and international trade, mainly exports of meat to China and other countries. As a net exporter of meat and meat products, the U.S. was forecast to dramatically increase its exports to China just before the pandemic hit. As China was emerging from a two-year trade war with the U.S. and a pork industry severely decimated by an outbreak of African swine fever, it was expected to be importing a lot of beef and other meats from the U.S. While U.S. exports of meat boost prices for U.S. farmers, its effects on retail prices paid by U.S. consumers deserve attention. To understand the nature of the price shocks in the meat market, a Seemingly Unrelated Regression Structural Vector Autoregressive (SUR-SVAR) model is developed to estimate the short-run and long-run dynamics of the meat industry. The models were applied to monthly poultry and meat export data from 2016 to 2021 to assess the short and long-run dynamics during the period by estimating the pre-Covid (2016-2019) and Covid (2022-2021) eras. Prices in Covid era was more than 20% higher than the post. Among the meat products, beef saw the highest price hike.

Objective 2: *Effects of International Trade on Food Security for Member Countries of AGOA.*

Seemingly Unrelated Variable Auto-Regression (SUR-VAR) models were applied to the country's major imports of grains, oilseeds, meats, and fruits; fertilizer and pesticides from 1990-2000. The contemporaneous prices were regressed on own-past prices, past and contemporaneous GDP, and Exchange rate to the dollar. An appreciation of the U.S. reduces imports of these commodities and inputs and exacerbates food insecurity.

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

All the studies conducted under objective 1 fall under government policies. Therefore, the direct beneficiaries are policy makers- politicians and other decision makers. Traders, shippers, producers, and rural economies would benefit only when these policy findings are implemented. The study under objective 2 can also be interpreted in a similar way in three other studies under policy. International trade agreement (whether regional trade, bilateral, or multinational) has to be approved by Congress, and they have their pros and cons. International agricultural trade make food and agricultural products available to

everyone globally. However, key international trade factors including exchange rates, GDP, and of course, export policies by exporting countries, and other trade regulations can severely impact consumers' access to food, and that include exchange rate to the U.S. dollar. Most imports are priced in the dollar, therefore an appreciation of the dollar relative other currencies to increase the import expenditure of these countries.

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 and foreign governments 'policies.
- 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. Two in-person presentations were made at the 2022 Annual Meetings of Southern Agricultural Science Association in New Orleans, LA, and the 2022 ARD Meetings in Atlanta. 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 12, 202; 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
1016556

Final Result: Phylodynamics of emerging plant pathogens

Final Result

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. *PLOS Computational Biology*, *18*(8), e1010422. 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. 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

4. **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.

DEVELOPED NEW TOOLS AND APPROACHES FOR UNDERSTANDING AND CONTROLLING PLANT AND HUMAN DISEASE: The continued emergence and spread of agricultural pathogens pose a major threat to agriculture. To enhance understanding of how new pathogens emerge and inform effective control and prevention strategies, NC State researchers are developing new statistical and computational methods for tracking the spread and evolution of plant pathogens using pathogen gene data. Over the past year, they have extended existing methods to meet several challenges posed by agricultural pathogens, including development of improved models for tracking the spread of plant diseases through complex agricultural landscapes, improved methods for tracking exchange of genetic material between different pathogen lineages, and improved methods for analyzing the effects of mutations and other genetic changes on pathogen spread. In addition to informing disease control in agriculture, these models and methods are increasingly being used to gain insights into human pathogens such as influenza, dengue viruses, and HIV, including the identification of major sources and drivers of disease transmission that can be efficiently targeted to support disease control. These findings have been shared through peer-reviewed publications and via high-quality, clearly documented open-source software for the analysis of pathogen genetic data.

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

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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.

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

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

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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.

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ECOLOGICAL AND BIOTECH-BASED APPROACHES TO CONTROL INSECT VECTOR-BORNE PLANT VIRUS DISEASES

Project Director
Dorith Rotenberg
Organization
North Carolina State University
Accession Number
1015290

Final Result: ECOLOGICAL AND BIOTECH-BASED APPROACHES TO CONTROL INSECT VECTOR-BORNE PLANT VIRUS DISEASES

Final Result

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

My project addresses the problem of chronic and emerging plant diseases caused by insect-transmitted plant viruses of economic significance to producers and consumers. With rising costs in crop production and disease management, my project aims to develop novel, effective and sustainable ways to control plant viruses diseases that rely on plant-to-plant spread by insect vectors. My project utilized state-of-the-art genomics, transcriptomics and proteomics tools to dig deeply into the mechanism of insect vector-plant virus-plant host interactions in order to find a means to disrupt the interaction in the virus transmission process.

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 major activities of this project made considerable progress on five fronts. 1) development and testing of advanced generations of transgenic tomato plants expressing hairpin RNAs that silence multiple species and genes of orthotospoviruses; 2) identification of insect vector proteins that interact directly with tospovirus proteins and/or respond to virus infection in two of the most important tissue systems involved in virus acquisition (gut) and inoculation of plant hosts (salivary glands). Remarkably, we isolated thrips saliva and identified proteins that may interact with plants and and orthotospoviruses. We are on the forefront of identifying biomarkers of vector competence through gene co-expression networks and characterizing the function of these insect vector proteins with regards to virus infection and host defense with the goal of developing new types of virus control and plant resistance to thrips. 3) development of functional genomics tools developed for larval stages of thrips vectors. This step was critical because no current tools available that silence genes associated with early infection of larval thrips by orthotospoviruses in the guts of these insects. This is the first step towards idenfication of gut molecules involved in virus entry. 4) develop genome editing tools for F. occidentalis, the first of its kind for a thysanopteran. This is another means for functional analysis of thrips genes by producing mutants and with a look to the future, it may be possible to use these insect engineering tools forthrips pest population suppression and a way to inhibit TSWV transmission to crops. 5) accumulated evidence on feeding and reproductive host range for the corn planthopper, and dispersion characteristics of this maize crop pest and vector of maize mosaic virus in mixed plant communities at mesocosm scale.

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

Deliverable front 1: Transgenic tomato resistant to multiple species and strains of orthotospovirus developed– durability of this resistance has led to new collaborations with an NCSU tomato breeder to introgress the virus-resistance trait into tomato breeding lines with other desirable traits.

Deliverable front 2: Basic research is still under way to discover the functional role of thrips proteins that could serve as targets for controlling the transmission of devastating plant viruses to crops and for developing plant resistance (genetic) and other technologies for controlling these devastating insects.

Deliverable front 3: The technologies developed can be used to identify genes and gene products associated with crop pest development and virus transmission competence - we may be able to use these tools to better understand plant virus entry into insect pests of agricultural crops and ways to disarm these mechanisms.

Deliverable front 4: To provide the first genome editing tools for any thysanopteran pests species or any member of the thysanopteran order. This was a proof-of-concept to use Cas9/CRISPr to produce knock-out (KO) mutants in two eye-color genes. KO lines have been established.

Deliverable front 5: We are using our basic knowledge of the ecology of the corn planthopper vector of maize mosaic virus (MMV) to embark on optimizing delivery of virus-vectors as functional genomics tools or biotech-based tools for plant gene modifications and for studying field-level disease outbreaks of MMV.

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

Arthropod-transmitted plant pathogens cause crippling monetary losses to U.S. and global economies. For example, there are reports that tomato spotted wilt, a world-distributed disease caused by an insect-transmitted plant virus, tomato spotted wilt virus (TSWV), can cause up to $1 billion in crop losses annually in the S.E. United States alone. Growers rely heavily on commercial insecticides to manage insect vector-transmitted diseases, however, resistance to these chemicals rapidly develops in repeatedly treated pest populations leaving few alternatives for controlling vector populations and the viruses they transmit.

The overarching goal of my program is to contribute alternative and sustainable tools for managing vector-transmitted crop diseases by applying new foundational knowledge about vector competence. Our vision for the future is that by disrupting these molecular interactions, grower communities will be equipped with new alternatives to reduce virus spread through croplands and together, will safeguard our earth's food supply. While the potential impacts of this project, like food security and safety (reduced use of pesticides), have yet to be realized by the broader public, our project has influenced the lives of graduate students and postdoc researchers who dedicate their professional lives to contributing to the understanding the threat of emerging plant diseases.

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.

Over the duration of this project (2018 - 2022)

Peer-reviewed publications:

*as corresponding; **as co-corresponding

Lee, G., Hossain, O., Jamalzadegan, S., Liu, Y., Wang, H., Saville, A.C., Shymanovitch, T., Paul, R., **Rotenberg, D.**, Whitfield, A.E, Ristaino, J.B, Zhu, Y., and Wei, Q. Abaxial leaf surface-mounted multimodal wearable sensor for continuous plant physiology monitoring (submitted for review, 9/1/22).

Bailey, S.T., Kondragunta, A., Choi, H.A., Han, J., **Rotenberg, D.**, Ullman, D.E., Benoit, J.B. Dehydration and infection elicit increased feeding in the western flower thrips, Frankliniella occidentalis, likely triggered by glycogen depletion. bioRxiv 2022.07.14.499040; doi: https://doi.org/10.1101/2022.07.14.499040 (submitted to journal, revision under review, 9/20/22).

Alviar KB, Rotenberg D, Martin KM, Whitfield AE. 2022. The physical interactome between Peregrinus maidis proteins and the maize mosaic virus glycoprotein provides insights into the cellular biology of a rhabdovirus in the insect vector. Virology 577:163-173. https://doi: 10.1016/j.virol.2022.10.002.

Rajarapu, S.P., Ben-Mahmoud, S., Benoit, J.B., Ullman, D.E., Whitfield, A.E., ***Rotenberg, D.** 2022. Sex-biased proteomic response to tomato spotted wilt virus infection of the salivary glands of *Frankliniella occidentalis*, the western flower thrips. Insect Biochemistry and Molecular Biology 149, 103843. https://doi.org/10.1016/j.ibmb.2022.103843.

Han, J., ***Rotenberg, D**. 2021. Integration of transcriptomics and network analysis reveals co-expressed genes in *Frankliniella occidentalis* larval guts that respond to tomato spotted wilt virus infection. BMC Genomics 22, 810. https://doi.org/10.1186/s12864-021-08100-4

Klobasa, W., Chu, F. C., Huot, O., Grubbs, N., **Rotenberg, D.**, Whitfield, A. E., and Lorenzen, M. D. 2021. Microinjection of corn planthopper, *Peregrinus maidis*, embryos for CRISPR/Cas9 genome editing. Journal of Visualized Experiments (169), e62417. https://doi.org/10.3791/62417

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Nachappa, P., Challacombe, J., Margolies, D.C., Nechols, J.R., Whitfield, A.E. and ****Rotenberg, D. 2020. Tomato spotted wilt virus benefits its thrips vector by modulating metabolic and plant defense pathways in tomato. Frontiers in Plant Science 11:1774. https://www.frontiersin.org/article/10.3389/fpls.2020.575564

***Rotenberg, D.**, Baumann, A.A., Ben-Mahmoud, S., Christiaens, O., Dermauw, W., Ioannidis, et al (plus **52 additional authors**). 2020. Genome-enabled insights into the biology of thrips as crop pests. BMC Biology 18: 142. https://doi.org/10.1186/s12915-020-00862-9.

Thomas, G.W.C., Dohmen, E., Hughes, D.S.T., Murali, S.C., Poelchau, M., Glastad, K., Anstead, C.A., Ayoub, N.A., ... **Rotenberg, D.**, et al. (plus **70 additional authors**). 2020. Gene content evolution in the Arthropods. Genome Biology 21:15. https://doi.org/10.1186/s13059-019-1925-7

Chen, Y., Dessau, M., **Rotenberg, D.**, Rasmussen, D.A., Whitfield, A.E. 2019. Entry of bunyaviruses into plants and vectors. In Advances in Virus Research, 104:65-96. https://doi: 10.1016/bs.aivir.2019.07.001

Badillo-Vargas, I.E., Chen, Y., Martin, K.M., ****Rotenberg, D.**, and **Whitfield, A.E. 2019. Discovery of novel thrips vector proteins that bind to the viral attachment protein of the plant bunyavirus, tomato spotted wilt virus. Journal of Virology 93 (21): e00699-19. https://doi: 10.1128/JVI.00699-19

Yao, J., **Rotenberg, D.**, and Whitfield, A.E. 2019. Delivery of maize mosaic virus to planthopper vectors by microinjection increases infection efficiency and facilitates functional genomics experiments in the vector. Journal of Virological Methods 270, 153-162. https://doi: 10.1016/j.jviromet.2019.05.010

***Rotenberg, D.**, and Whitfield, A.E. 2018. Molecular interactions between tospoviruses and thrips vectors. Current Opinion in Virology 33:191–197. https://doi:10.1016/j.coviro.2018.11.007.

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Invited talks:

Genome-enabled insights into thrips as crops pests and virus vectors, Super Vectors Symposium. Joint ESA-SEB / APS-CD Conference in San Juan, Puerto Rico. March 29, 2022.

Molecular interactions between thrips and tospoviruses: Advances in defining determinants of thrips vector competence. Department of Biological Sciences, Seminar Series, University of Cincinnati, OH, March 29, 2021.

It takes a lot of guts: characterizing the early response to tomato spotted wilt virus infection in larval thrips. The Entomological Society of America Annual Meeting, Plant-Insect Ecosystems Section Symposium: Transmission Ecology of Vector-borne Phytopathogens, St. Louis, MO, Nov 20, 2019.

Molecular interactions between tospoviruses and thrips vectors. International Society - Molecular Plant Microbe Interactions, XVIII Congress, Satellite Meeting: Dynamics and Mechanisms of Insect-Transmitted Pathogens, Glasgow, Scotland, UK, July 14, 2019.

Contributed to presentations by student and postdoc mentees

Marlonni Maurastoni, Yuting Chen, Jinlong Han, Ruchir Mishra, Bryony C. Bonning, Moshe Dessau, **Dorith Rotenberg**, and Anna E. Whitfield. Identification of tomato spotted wilt virus glycoprotein GN domains that bind to thrips guts. American Society for Virology, July 16-20, 2022. Madison, WI, USA. (Poster)

Hao Wei Teh, Karen Barandoc-Alviar, **Dorith Rotenberg**, Cesar Xavier, Kathleen Martin, and Anna Whitfield. Deciphering the interactions between maize mosaic virus and its insect host, *Peregrinus maidis*. American Society for Virology, July 16-20, 2022. Madison, WI, USA. (Poster)

Rajarapu, S.P., and **Rotenberg, D.** Sexually-dimorphic proteomic responses of *Frankliniella occidentalis* salivary glands to tomato spotted wilt virus infection. Entomological Society of America Conference, Denver, CO, Oct 31- Nov 3, 2021 (*in-person oral presentation*). *SPR *awarded NCSU Professional Development Award for Post Docs (Travel Award)*

Han, J., Barandoc Alviar, K., Whitfield, A., and **Rotenberg, D.** Identification of a transcriptionally-responsive, TSWV-interacting protein in *Frankliniella occidentalis* first instar guts. Entomological Society of America Conference, Denver, CO, Oct 31- Nov 3, 2021. * *JH received 1st prize for student oral presentation (in-person) in the "P-IE Vectors" Session*

Rajarapu, S.P., and **Rotenberg, D.** Sex-specific salivary gland proteome of a thrips vector. Virtual Southeastern Branch Meeting, Entomological Society of Entomology, March 29 – 31, 2021.

Han, J. and **Rotenberg, D.** Integration of transcriptomics and network analysis reveal co-expressed genes in *Frankliniella occidentalis* guts that are responsive to tomato spotted wilt virus infection. Virtual Southeastern Branch Meeting, Entomological Society of Entomology, March 29 – 31, 2021. * *JH received 1st prize for student oral presentation*

Lorenzen, M., Klobasa, W., Huot, O., Grubbs, N., **Rotenberg, D.**, and Whitfield, A. Application of new genomic tools and techniques in arthropods. International Plant & Animal Genome XXVIII, San Diego, CA, USA, January 11-15, 2020.

Han, J., and **Rotenberg, D.** Transcriptomic response of *Frankliniella occidentalis* guts to tomato spotted wilt virus infection. Emerging Plant Disease – Global Food Security Cluster Symposium: Outbreaks: Tackling Emerging Plant Diseases That Threaten Food Security, NCSU, Raleigh, NC, Jan 10, 2020.

Han, J. and **Rotenberg, D.** Transcriptomic response of *Frankliniella occidentalis* guts to tomato spotted wilt virus infection. Entomological Society of America Conference, St. Louis, MO, November 17-20, 2019. *JH received 2nd prize for poster presentation.

Ben-Mahmoud, S.K., Benoit, J., **Rotenberg, D.**, Ullman, D. Impact of virus infection on transcript expression in the salivary glands of *Frankliniella occidentalis* and potential effects on plant defense. XI International Symposium on Thysanoptera and Tospoviruses (ISTT), Kunming, China, September 23, 2019.

Rotenberg, D., and Whitfield, A.E. Molecular interactions between tospoviruses and thrips vectors. International Society - Molecular Plant Microbe Interactions, XVIII Congress, Satellite Meeting: Dynamics and Mechanisms of Insect-Transmitted Pathogens, Glasgow, Scotland, UK, July 14, 2019.

Chen, Y., Badillo-Vargas, I.E., Martin, K.M, **Rotenberg, D.**, and Whitfield A.E. Characterization of novel thrips vector proteins that bind to tomato spotted wilt virus. The American Phytopathological Society Meeting, Cleveland, OH, August 3-7, 2019.

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.

DEVELOPED NEW INSIGHTS, TOOLS, AND APPROACHES FOR PREVENTING THE SPREAD OF HIGHLY DAMAGING PLANT VIRUSES: Insect-transmitted plant diseases cause crippling monetary losses to US and global economies. To reduce these losses, NC State researchers are working to develop new, effective, and sustainable ways to control insect-transmitted plant viruses. The milestones they have achieved so far include the development and testing of tomato plants with the genetic ability to neutralize an important genus of viruses (orthotospoviruses), the identification of proteins found in the gut and salivary glands of insects involved in viral transmission (including transmission of the tomato spotted wilt virus, one of the most destructive crop viruses in the world), and the development of new tools that will support analyzing and engineering insect genes in order to naturally suppress their ability to transmit harmful viruses to plants. These insights represent the groundwork for new approaches to enhancing food security and safety, and they have already led to new collaborations with an NC State tomato breeder to incorporate viral resistance into tomato breeding lines, new biotech-based tools for plant gene modification and the study of field-level disease outbreaks, and numerous peer-reviewed publications.

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

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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.

x

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

x

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

x

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.

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Management of Arthropood Pests on Tree Fruits and Vegetables in North Carolina

Project Director
James Walgenbach
Organization
North Carolina State University
Accession Number
1013695

Final Result: Management of Arthropood Pests on Tree Fruits and Vegetables in North Carolina

Final Result

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

The brown marmorated stink bug, twospotted spider mite and western flower thrips are important pests of fruit and vegetable crops in North Carolina. Current management practices are either ineffective or rely on excessive pesticide use that represents a hazard to farm workers 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.

Studies were conducted to determie the distribution of brown marmorated stink bug (BMSB) in NC, and factors regulating establishment in different regions of the state. Climatic conditions in the mountains and western Piedmont region were found to be ideal for BMSB establishment, while heat stress related to high temperatures in the eastern Piedmont and Coastal Plain regions during July and August suppressed establishment of the pest. A degree-day model that predicted BMSB population development was developed whereby cumulative degree-days beginning on 1 April (13.5 hr photoperiod that triggers initiation of reproductive development) accurately predicted emergence of first generation adults. Dispersal of first generaiton adults from wooded habitats into crops is the most damaging stage of the pest, and this model provides growers a tool to time insecticide applications for judicious pesticide use.

Studies were also conducted to evaluate an attract and kill (A&K) technique for managing BMSB in apple orchards. A 3X Duel Pheromone lure attractant (aggregation pheromone + synergist) was attached to insecticide-impregnated netting (killing agent), and placed at the interface of woods and apple orchards in an attempt to intercept stink bugs before entering orchards. While A&K stations killed hundreds of stink bugs, no reduction in damage to apples was observed. With two years of negative results, the strategy as tested was deemed unlikelty to provide benefit to apple producers.

Experiments to obtain additional data on the performance of different stratins of the specialist predatory mite Phytoseiulus persimilis (reared on beans versus tomato) for suppression of twospider spider mite on tomato were initiated in commercial fields of tomatoes. Unfortunately, extremely high populations of western flower thrips (WFT) outcompeted spider mites for resources, and the study was abandoned. However, populations of WFT were collected and evaluated for resistance to spinetoram (Radiant), the most effective insecticide agaisnt WFT. Resistance levels >1000X were detected in the Piedmont of NC (Rowan), while populations remained susceptible in tomato production areas in the moutnains. These results provided information to growers that indicated alternative insecticide options are necessary in the Piedmont.

Several insecticide trials were conducted to evaluate the efficacy of a variety of exisiting and experimental insecticides for control of key pests of fruiting vegetables, apples and peaches. The most promising new production was Plinazolin, a new mode of action that provided outstanding control of thrips, spider mites, and plum curculio, and is expected to be widely used product when registered on fruit and vegetable crops (expected in 2024). A gel formulation of pheromone was compared to the standare Isomate CM-OFM TT dispensers for mating disruption of the codling moth and oriental fruit moth in apples.The new gel substance was equally effective to Isomate dispensers in suppressing codling moth captures in pheromone traps, but but less effective in suppressing oriental fruit moth captures. Differences in trap captures were most pronounced when using enhanced OFM lures containing host-plant induced volatiles.

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

The target audience included commercial producers of fruit and vegetable crops, extension personnel assisting producers, and the crop protection industry. Benefits from the program included providing clientile with tools to use insecticides more judiciously for management of brown marmorated stink bug (eliminating applications before models predicted adult emergence), providing recommendations on a local scale as to the efficacy of different pesticides for suppression of thrips, and providing unbiased infromation on the comparison of different pest control products including mating disruption dispensers and insecticides. Educational programs on the biology and ecology of key pests provided clientile with new knowledge to better understand the use of pest development models.

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

The overall goal of the project was to improve the pesticide-applicaiton decision process among growers and consultants, including timing of applications to maximize benefit and reduce unnecssary use, and selection of products that have friently environmental and human health profiles. This serves to minimize environmental impacts of farming, including water resources, and ensure a plentiful, safe and inexpensive source of food for the general population.

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.

DISCOVERED NEW INSIGHTS FOR SAFELY CONTROLLING KEY FRUIT AND VEGETABLE PESTS: The brown marmorated stink bug (BMSB) and western flower thrips (WFT) are important pests of fruit and vegetable crops in North Carolina. Current management practices are either ineffective or rely on excessive pesticide use that represents a hazard to farm workers and the environment. To address this challenge, NC State researchers conducted studies to determine the population distribution of the BMSB in NC and established an effective model to predict BMSB population development, providing growers with a new tool for precisely timing insecticide applications for maximum efficiency. Additional experiments revealed that WFT populations in the Piedmont are highly resistant to spinetoram (Radiant), the most effective insecticide against WFT, alerting growers in this region to take alternative measures. The researchers also identified several promising new and experimental insecticides for controlling key pests of fruiting vegetables, apples, and peaches. By helping growers reduce the environmental impact of pesticides and ensure a plentiful, safe, and inexpensive food supply, these studies not only benefit commercial producers but also Extension personnel, the crop protection industry, and the general population.

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

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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.

x

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

x

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

x

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.

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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

Final Result: Translational approaches to improve management strategies for cucurbit and sweetpotato diseases in North Carolina

Final Result

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

Vegetables are important crops in North Carolina, with a farm gate value of over $2 billion. Diseases caused by plant pathogens such as oomycetes, fungi, bacteria, and nematodes limit vegetable production and quality, and in some cases, threaten the survival of the vegetable industry. Translational research is needed to avoid crop losses due to disease and ensure continued productivity of the vegetable industry in North Carolina. My program focuses on studying diseases of cucurbits and sweetpotato with the ultimate goal of delivering science-based disease management recommendations to growers in North Carolina and advance our knowledge in the field of vegetable pathology.

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.

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.

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, registration of novel active ingredients for chemical control through collaborations with fungicide companies, and release of commercial pickling cucumber varieties with tolerance through collaborations with seed companies. 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.

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.

Approach: 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 went 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.

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*.

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.

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

Global food security is a major issue in the world today, and the importance of vegetable crops cannot be overstated. Vegetable crops are a major source of vital nutrition to many people, providing essential vitamins and minerals in a highly accessible and affordable form. They are also a key component in providing dietary diversity, which is essential to a healthy diet. The world's food security is under increasing threat from crop diseases. According to the Food and Agriculture Organization of the United Nations, one out of every three food crops is lost to diseases each year, resulting in an estimated loss of US$220 billion annually. This is a problem that affects farmers, consumers and entire nations. In order to combat crop diseases, farmers must employ a variety of measures, including crop rotation, using resistant varieties, and using fertilizers or fungicides. Unfortunately, these measures often come at a great economic cost, making it difficult for farmers in developing countries to protect their crops. In addition, climate change is a major contributor to the spread of crop diseases. As temperatures rise and regions become more arid, plants become increasingly vulnerable to disease. This further threatens global food security. It is clear that diseases of vegetable crops are a major threat to global food security. Without proper measures to protect vegetable crops, the world's food supplies could be compromised. It is therefore essential that governments, farmers, and organizations take steps to reduce the spread of vegetable crop diseases and protect global food security.

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 have been disseminated through websites, social media, oral and poster presentations of research results during extension (grower meetings, county workshops, production meetings, and field days among others) and scientific meetings, and publication of book chapters, peer reviewed research articles, and abstracts in conference proceedings.

Extension activities in the lab will be focused on delivering information to vegetable stakeholders about diagnostics and control of vegetable pathogens. We will use web-based resources, extension publications, workshops, grower group presentations, and field days to deliver educational programs. We will continue to provide diagnostic support and recommendations for vegetable samples submitted to the clinic. We will continue to conduct vegetable disease control demonstration trials in collaboration with growers and industry to improve pathogen management recommendations.

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.

DELIVERED HIGH-IMPACT APPROACHES AND TOOLS FOR MANAGING DISEASE IN SWEET POTATO AND GOURD CROPS: Vegetables are important crops in North Carolina, with a farm gate value of over $2 billion. Plant diseases limit vegetable production and quality and, in some cases, threaten the survival of the industry. To address these threats, NC State researchers are studying diseases of sweet potato and cucurbits (the gourd family, which includes cucumbers). To date, they have partnered with growers, packers, Extension agents, and industry stakeholders, developed a field biosurveillance system, and supported the release of new cucumber varieties to drive effective, precise management of the devastating disease cucurbit downy mildew. They have also established strong collaborations with chemical companies and the USDA's IR-4 project to secure registration for five new fungicides to combat the epidemic of sweet potato black rot, reducing disease losses from 40% to 5% and preventing an estimated $116 million in losses for NC growers. They are currently working to reduce trade barriers to sweet potato exports and have already collaboratively secured a $1.5 million grant to continue expanding NC sweet potato exports while safely and effectively controlling post-harvest disease. Their efforts have also

reduced the need for fungicide sprays, saving NC growers approximately $2.5 to $6 million annually. This research has been shared through websites, social media, presentations to growers and academics, and peer-reviewed articles, benefitting not only NC growers and consumers but also the global supply of these important crops.

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

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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.

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

x

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

x

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.

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Consumer Horticulture

Project Director

Lauren Hargrave

Organization

North Carolina Agricultural and Technical State University

Accession Number

7001858

Annual Result: Beekeeping

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

There is a national trend of honeybee decline across the nation. This is a problem for all beekeepers and farmers who depend on honeybees to pollinate a large portion of their crops. Without honeybees, our food supply would be in jeopardy. Beekeeping is an activity that requires specific knowledge and skills to be successful. However, there are limited educational opportunities available to aspiring beekeepers. Education is necessary for those interested in honeybees to move forward with their interest in beekeeping.

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.

Agriculture and Natural Resources (ANR) agents across four counties (Union, Robeson, Vance, and Columbus) held monthly meetings with local and state beekeeper associations, provided training and technical assistance, and conducted an annual beekeeper school, making 757 contacts across 37 interactions.

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

The ANR agent in Vance County held monthly meetings with the Kerr-Tar Beekeepers Association. These meetings were conducted face-to-face and through Zoom. During these meetings, the agent provided the beekeepers with recommended beekeeping education and made hive visits to assist beekeepers when they had problems. The agent also partnered with WIZS radio to conduct programs on beekeeping and the importance of honeybees. The 10 Kerr-Tar Beekeepers surveyed in November stated that their knowledge of beekeeping had increased by following Cooperative Extension recommendations. Working with Cooperative Extension has helped them educate the general public about the importance of honeybees. The beekeepers also stated that the public is learning to call Cooperative Extension when they have bee swarms on their property. Cooperative Extension has a list of beekeepers who will come out and collect these swarms. In 2022 seven swarms were saved by this partnership with Cooperative Extension.

Columbus County Beekeepers started training for new beekeepers in February 2022. The Columbus County Extension Center provided space for 24 people to meet and train for three consecutive days. The Columbus County Cooperative Extension Agricultural Technician assisted with the instructional program during the training. Participants learned beekeeping skills and met with experienced beekeepers. After four months of learning about beekeeping and beehive manipulation, each participant received a certificate of completion in June. A final review and test were given to the participants who completed the training in June. By the end of the training course, 11 participants had purchased two or more beehives and caught swarms. Another six had one hive only. Due to this success, plans are in place to hold more new beekeeper training sessions

The Union County Small Farm Extension Program provides a beginner bee school in collaboration with the Union County State Beekeepers Association (UCSBA). This collaboration started in 2018 and offers a beginner bee school at least once annually. Bee school covers the biology and management of honeybees, providing the information necessary to begin as a beekeeper. As a result of the partnership between N.C. A&T Extension and the UCSBA, 353 people have been trained to keep bees since 2018. This increase in new beekeepers contributes to the conservation of honeybees in Union County and the surrounding area, as well as an increase in the number of members in the Union County State Beekeepers Association. This increased membership allows the UCSBA to do more community outreach, educating the public about the importance of honeybees to our food system. As this partnership moves forward, we expect more beekeepers in Union County and a greater appreciation for honeybees in our community.

The ANR agent in Robeson County and the Robeson County Area Beekeepers facilitated Beginning Beekeepers Schools. The topics taught included: Introduction to Beekeeping, Opening the Hive, Honeybee Pests, Basic Equipment for Beekeepers, and How to Become a Master Beekeeper. Subjects were taught by experienced beekeepers and provided attendees with the tools needed to be successful. A total of 26 people attended the school. Evaluations conducted after the schools showed that 85% of the participants stated they gained the knowledge needed to be successful beekeepers. Since attending the school, nearly half of the participants have become members of the Robeson County Area Beekeepers and the North Carolina State Beekeepers Associations. They are on their way to becoming experienced beekeepers. With the increased visibility and the number of new beekeepers, the increased demand for local honey will be met, and the association will continue to be viable.

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

Providing beekeeping programs helps to ensure food supply for communities are not in jeopardy.

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 nationwide decline of honeybees poses problems for farmers who depend on bees to pollinate many of their crops, and that means it could threaten the entire food supply. Beekeeping can help, but it requires specialized skills and there are limited educational opportunities for aspiring beekeepers. Agriculture and Natural Resources (ANR) agents across four counties (Union, Robeson, Vance, and Columbus) held monthly meetings with local and state beekeeper associations, provided training and technical assistance, and conducted an annual beekeeper school, making 757 contacts across 37 interactions. The agents worked with local beekeeper associations, made hive visits to beekeepers with problems, conducted rsdio programs on the importance of honeybees and offered education for new and experienced beekeepers. Educational topics included introduction to beekeeping, opening the hive, honeybee pests, basic equipment for beekeepers, and how to become a master beekeeper.

Annual Result: Plasticulture Rental and Cashback Program

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

Single-use plastics are a major environmental concern. Most plastic mulch is used once and then either stored, burned, or put in landfills, as recycling is not widely available. More research and development are needed on degradable mulch materials to reduce plastic's negative environmental aspects.

Production using plasticulture is proven to increase yield and extend the growing season for small farmers. Plasticulture can also reduce environmental impacts by locking planet-warming carbon in the ground, reducing water consumption, and protecting against pests without the use of chemicals. Conventional agriculture technologies are insufficient to meet the food needs of a world population that will reach 9.3 billion by 2050 (Food and Agriculture Organization of the United Nations, 2009). To meet this challenge, small farmers require access to affordable plasticulture equipment as well as training in plasticulture production methods and the safe operation of plasticulture equipment.

Due to the high initial cost of purchasing plasticulture equipment, small farmers do not routinely take advantage of the benefits of plasticulture production. Adopting plasticulture production can potentially increase yields and profits for NC small farmers. Farmers will need to produce 60% more food by 2050 to meet the needs of a growing 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 N.C. A&T Plasticulture Rental/Cash Back Program provides plasticulture equipment as a low-cost rental and training in the plasticulture method for small farmers. The program provides low-cost rental equipment and training to small farmers. The program also trains Extension agents, equipping them with the tools to assist small farmers in their counties with plasticulture operations.

N.C. A&T continues to offer plasticulture equipment to N.C. small farmers at a nominal cost. The program provided three agent training sessions in 2022 during Small Farms Week and at the State Extension Conference. These sessions featured classroom presentations (State Extension Conference) and field demonstrations (Small Farms Week, State Extension Conference). Also, as per agents' requests, the field demonstrations featured degradable mulch trials, an area of research agents indicated was essential to meeting farmer requests for information..

To address this need to reduce single-use plastics, the N.C. A&T Plasticulture Program began testing degradable mulches in 2022. This work will continue in 2023, enlisting partners within Extension as well as industry professionals. Funding for a Capacity Building Grant is being sought to expand the research effort.

It is anticipated that as degradable mulch technology advances and the cost of materials decreases, more small farmers will adopt plasticulture practices. A positive environmental impact should be observed in the form of reduced plasticulture waste going into landfills. For 2023, trials using biodegradable and pigmented mulches will continue at the University Farm.

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

Small farmers benefitted from the continued availability of N.C. A&T-owned plasticulture equipment. In 2022 there were 10 first-time farmer participants in the N.C. A&T Plasticulture Rental/Cash Back Program, increasing the number of small farmers adopting the plasticulture method. These farmers expanded their operations to include plasticulture-grown vegetables, berries, cut flowers, and row crops. These crops were grown on eight additional acres of land that previously were not in cultivation. One small farmer reported purchasing his own plastic mulch layer due to practical experience and knowledge gained through low-cost N.C. A&T program, which is a goal stated in the program initiation.

Small farmers benefitted from plasticulture updates provided during the annual Small Farms Week and Small Farms Field Day. Farmers received updates on pigmented and degradable mulch technology and observed trials at the University Farm. N.C. A&T research continues to provide small farmers with knowledge of the varied types of plastic mulch available, enabling them to match crops with specific mulch for optimal crop production, increasing yield.

2022 program statistics

- N.C. A&T-owned equipment was rented by 24 small farmers in five NC counties who could not otherwise afford it.

- Total cost to small farmers: $1,300.?
- Total savings to small farmers: $63,590.
- There were 10 first-time N.C. A&T plasticulture program participants.
- There were four first-time plasticulture users.
- One small farmer became a certified organic producer.
- Five small farmers began to use organic principles.
- 10 small farmers became conventional producers.
- Crops grown:
    - Vegetables?
    - Cut flowers?
    - Berry crops (high tunnel and field)
    - Row crops?

In 2022, the three training sessions included 87 small farmers who increased their knowledge in: (a) best practices for enhancing flower production volume and profit using plasticulture; (b) how to reduce weed and disease pressure using plasticulture in cut flower production: (c) how to make targeted fertilizer applications resulting in reduced fertilizer use and reduced input costs; (d) the proper use of drip irrigation- a vital component of the plasticulture system- to reduce water usage and increase watering efficiency by making targeted water applications to the plant root zone;(e) the proper use of fertigation- fertilizers applied through the drip irrigation lines- to reduce fertilizer costs and make targeted fertilizer applications to the plant root zones for increased fertilization efficiency; (f) safely connecting and operating a plastic mulch layer; (g) utilizing plasticulture production methods to increase crop yield and quality, get better weed control, use less water and fertilizer; and extend the growing season; and (h) new and innovative mulch materials such as pigmented and degradable mulches and their effects on crops and the environment.

Additionally, 26 ANR agents participated in training that increased their knowledge in:

1. New and innovative mulch materials such as pigmented and degradable mulches and their effects on crops and the environment.
2. Sharing results of research trials testing tomatoes grown on five types of degradable plastic mulches.
3. Determining which degradable plastic mulch materials perform best for tomato production.

4. Sharing research trial results of watermelon grown on six types of pigmented plastic mulches.

5. Evaluating which plastic mulch materials performed best for watermelon production.

In Watauga County, the N.C. A&T ANR agent has promoted plasticulture solutions among the range of possible technologies for nearly two decades. Over time, the two mulch layers and one mulch lifter have become routinely in demand by more than three dozen area growers, while about a half dozen farms formerly renting the mulch layers have now purchased their own. Extension also guided growers toward options of geotextile mulches, caterpillar tunnels, and high tunnels as appropriate. N.C. A&T Extension's programming aided three area farms in receiving cost shares from UISDA's Natural Resource Conservation Service (NRCS) for high tunnel construction. Additionally, we worked with seven other local farms to set up new or additional high tunnels for greater season extension and crop rotation flexibility through the 2021-2022 years. Additional farm revenues and cost savings due to adoptions of drip irrigation, plastic mulch, geotextile mulch, row covers, and greenhouse tunnel plastics exceeded $170,000 across participating farms in Ashe and Watauga counties during that time.

The Plasticulture program spent more than $15,000 to provide equipment to Caswell County. Small farmers and limited resources farmers can rent the layer for $25 a day, which is much cheaper compared to buying plasticulture machinery. Twelve farmers used plastic mulch layers for on total of about 18 acres. A plastic mulch layer costs about $3,500, which adds up to about $40,000 in savings for these small farmers. They also benefited from increased yields and savings on fertilizer costs. We are striving to expand the program to surrounding counties to increase the number of farmers who will benefit from this program.

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

Reduced irrigation water usage for agriculture reduces stress on local and regional drinking water supplies. Continued training for small farmers will ensure that more farmers can implement plasticulture production methods, producing the extra food required in the future. As more plasticulture acres come into production, reducing the amount of single-use plastic going into landfills will be a crucial area of research and development.

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.

Continued broad, public opposition to plasticulture remains a barrier to wider adoption of the plasticulture method. This is mainly due to the large amount of plastic waste generated. The widespread adoption of degradable mulches remains stunted due to the increased cost and reduced tensile strength of these materials. Farmers are reluctant to adopt mulches made from recycled plastic, having doubts about the durability of such materials. N.C. A&T ANR agents, at times, appear reluctant to fully embrace the program, even though the benefits to farmers are undeniable. Equipping all rental locations with trailers to transport the equipment would, in part, address this concern.

Training and professional development provided- number of attendees is in parentheses.

For Small Farmers

02/28- Rowan County- Plasticulture for Cut Flower Production (5)

03/22- Small Farms Week- Fertigation and drip irrigation in high tunnels (15)

04/20- Conetoe Family Life Center- Plasticulture production and plastic layer set up and operation (7)

05/09- Franklin County High Tunnel Field Daye Plasticulture in High Tunnels (30)

06/10- Small Farms Field Day University Farm- Plasticulture Field Trials update (30)

For Cooperative Extension ANR Agents

08/11- Faculty Staff Institute- Plasticulture Field Trials Update for NC A&T ANR Agents (8)

10/04- State Extension Conference- Plasticulture Field Trials Update for NC State and NC A&T ANR Agents (5)

10/04- State Extension Conference Presentation- Results of Pigmented and Degradable Plastic Mulch Trials at the NC A&T University Farm (13)

For 2023

Trials using biodegradable and pigmented mulches will continue at the University Farm. A capacity-building grant proposal, submitted in 2022, if funded, will encompass further research into biodegradable mulches involving Extension experts and industry partners. The funded projects will be notified in the summer of 2023.

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.

Production using plasticulture is proven to increase yield and extend the growing season for small farmers. Plasticulture can also reduce environmental impacts by locking planet-warming carbon in the ground, reducing water consumption, and protecting against pests without the use of chemicals. However, due to the high initial cost of purchasing plasticulture equipment, small farmers do not routinely take advantage of its benefits. The N.C. A&T Plasticulture Rental/Cash Back Program provides plasticulture equipment as a low-cost rental and training in plasticulture methods for small farmers. The program also trains Extension agents, equipping them with the tools to assist small farmers with plasticulture operations. In 2022 10 first-time farmers participanted in the Rental/Cash Back Program. These farmers expanded their operations to include plasticulture-grown vegetables, berries, cut flowers, and row crops. Additionally, Extension offered a variety of training programs on plasticulture production Extension also began research into using biodegradable and pigmented plastic mulches.

Plant Production Systems

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

Annual Result: On-Farm Demonstrations

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

Small, beginning, limited resource, and socially disadvantaged farmers in northeastern North Carolina are targeted by USDA's Natural Resources Conservation Service (NRCS) for program participation. One popular program is the installation of high tunnel structures for growing specialty crops and extending the typical growing season in North Carolina through an NRCS cost share program. Profitably managing high tunnel production on a very small scale takes excellent knowledge. Without research-based information, these farmers learn by trial and error, often resulting in failure and abandonment of the high tunnel structure. In order to comply with USDA-NRCS requirements, the farmer must continue to produce a crop for several years or pay back the amount of money provided by USDA as cost-share for building the structure. The farmer also has money invested since it costs more to purchase, construct and outfit a high tunnel than the dollars provided through cost share funds.

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.

Monthly high tunnel meetings were held on a rotating basis at the farms involved with the High Tunnel Crop Demonstration Plots program. The N.C. A&T Cooperative Extension publication ***High Tunnel Production*** by Dr. Sanjun Gu was used throughout this project and is a valuable resource in the field.

In 2022 the crops used for demonstration were personal-sized specialty melons (cantaloupe, watermelon, and Crenshaw), three types of gourmet cucumbers, and heirloom slicing tomatoes. Transplants of each of the plant species were provided to the farmers involved in the demonstration plot. During each of the monthly meetings, different production topics were discussed and demonstrated. Topics included:

1. Transplant production and species and variety selection.
2. Record keeping.
3. Drip irrigation installation.
4. High tunnel temperature and ventilation control and monitoring.
5. Soil fertility, plant spacing, and utilizing high tunnel space efficiently.
6. Plant trellising and pruning techniques.
7. Record keeping, harvesting, quality control, and packaging.
8. High tunnel sanitation, weed control, and integrated pest management.
9. Season extension techniques within high tunnels.
10. Marketing and sales avenues.

The monthly high tunnel meetings on the demonstration farms provided time for hands-on learning of techniques necessary to produce high-tunnel fruits and vegetables. By visiting different farms, participants learned from the successes and failures of the various farms. The difficulties of controlling high tunnel climate (primarily temperature and ventilation) and pests were apparent at the demonstration farms. They provided opportunities to demonstrate management and IPM techniques to mediate the issues.

By working through a complete season, growers could visualize the differences in planting and harvesting timing between field and high-tunnel crops and learn more about techniques that improve the quality of the produce in the high tunnel. Record-keeping was minimal but emphasized planting date, harvest date, amount harvested, amount saleable, and amount sold.

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

The target audience of this project was small, beginning, limited resource, and socially disadvantaged farmers who have received or are planning to apply for USDA NRCS cost-share for a high tunnel. The project was targeted at farmers in Warren and Halifax counties. It included four farms with demonstration plots installed in high tunnels. One grower had produced

vegetables for one year before the project began. The other three farmers had never grown anything in their high tunnels. The project also included six to 10 additional farmers with brand new high tunnels or still involved in the application phase with USDA-NRCS.

As a result of the project, this group of farmers learned a great deal about the importance of monitoring and managing the temperature and ventilation in high tunnels for vegetable production.

At the beginning of the project, the group did not realize the time and effort required to control high tunnel temperature and ventilation throughout the day by raising and lowering sidewalls and opening doors and louvered vents. Several growers were motivated to install horizontal airflow fans to better sustain appropriate temperatures and humidity for plant growth in the tunnel. Every farmer modified their existing high tunnel to better control drainage in and around the high tunnel and to eliminate points of cold air entry that could kill high tunnel crops during the extended season.

Farmers involved with this project learned the value of trellising high tunnel fruiting plants to conserve valuable space, better monitor fruit development and ripening, and monitor for insect pests and diseases. For example, one of the demonstration high tunnels suffered a severe outbreak of tomato hornworms that was visible immediately and contained by trellising the tomato plants.

Over half of the farmers in the project have grown vegetables in the field for themselves or to sell on a small scale. Our demonstration plots helped these farmers realize the dramatic shift in the calendar for the harvest of ripe produce when using high tunnels. At one demonstration plot, the specialty melons we included were not harvested at their peak and were mostly discarded as overripe since the small farmer was timing his harvest based on past field harvests of melons.

The participants learned to appreciate the cucumber, melon, and tomato varieties in the demonstration plots. These varieties were selected specifically for their taste and texture and would bring a premium price along with consumers.

Every participant installed drip irrigation for more consistent and less labor-intensive watering of crops, and only one had been using any irrigation system before this project. That particular grower switched from unreliable soaker hoses to a drip system that can be regulated and used to deliver nutrients.

In the project's first year, the participants were unaware of the length of season extension possible in their high tunnel. Their planting, harvesting, and replanting calendar will be shifting by over a month in the coming season (2023) based on what they learned during the 2022 project.

This project will continue in 2023, emphasizing post-harvest handling, packaging, and marketing. During the project, some produce grown in the high tunnels was sold to consumers. However, most of it was shared with neighbors and donated to local food pantries.

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

During the project, some produce grown in the high tunnels was sold to consumers. The availability of fresh fruits and vegetables in many Tier 1 counties is limited, so this directly benefits the public. In addition, a great deal of the produce was shared with neighbors and donated to local food pantries.

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 will be continued in 2023, emphasizing post-harvest handling, packaging, and marketing. One of the biggest challenges was providing an ongoing example of how various practices and techniques should be maintained and demonstrating the maximum capacity for production in a high tunnel. We plan to have a high tunnel demonstration constructed at the Currituck County Extension office complex in 2023, which will provide an example so northeast North Carolina growers can understand the full benefit of high tunnel production in USDA Hardiness zones 8b, 8a, and 7b.

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.

Cooperative Extension at N.C. A&T works with farmers applying for USDA's Natural Resources Conservation Service (NRCS) cost share program to teach them about high tunnel agriculture and help them install and use high tunnels on their farms. In 2022, monthly high tunnel meetings were held on a rotating basis on farms involved in the High Tunnel Demonstration Plots

program. The meetings provided hands-on learning of high tunnel growing techniques for fruits and vegetables, and allowed farmers to learn about high tunnel successes and failures through the farm visits. The project targeted farmers in Warren and Halifax counties and included four farms with demonstration plots installed in high tunnels. Farmers saw how high tunnels can dramatically lengthen their growing seasons and therefore offer a chance at higher profits. They learned about drip irrigation, pest control, drainage, and eliminating cold air leaks that could kill crops during the extended season. Produce grown in the demonstration tunnels was donated to food pantries and sold at local markets. The project will continue in 2023 emphasizing post-harvest handling, packaging, and marketing.

Annual Result: Organic and Sustainable Agriculture

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

Heavy chemical inputs and intensive soil disturbance in agricultural production threaten the sustainability of U.S. agriculture. Organic and sustainable agriculture production systems respond to site-specific conditions by integrating cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity. Organic and sustainable farming practices help small, limited-resource farmers improve the health of their farmland, help them make more profits, and improve the quality of their communities. The local food movement provides small and limited-resource farmers great opportunities to transition conventional production into organic and sustainable production, especially with specialty crops such as vegetables and small fruits.

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 2022, we continued the Diverse Native Hedgerow for Pollinators project. Having diverse plants with overlapping and successional blooms through the growing season provides nectar and pollen with shelter and nesting sites for pollinators and natural enemies (predators and parasitoids) of crop pests. This demonstration continued offering learning opportunities for farmers and agents to use nature to solve pest and production challenges. Results of this project translated into a workshop of "Creating Habitat for Pollinators to Thrive on Your Farm" at the Sustainable Agriculture Conference organized by the Carolinas Farm Stewards Association (CFSA), with more than 55 participants.

The NC Sustainable Agriculture Research and Education (SARE) program offered scholarships for professional development to Extension personnel and agricultural professionals, sent 29 Extension agents to the CFSA Sustainable Agriculture Conference, and provided conference support for 15 speakers/presenters for an interactive virtual conference. As the Northern SARE coordinator, N.C. A&T's horticulture specialist also attended the Southern SARE coordinators' summer meeting in Memphis, TN. We offered a demonstration of tomato, pepper, eggplant, and ethnic vegetables (bitter melon, luffa, and winter melon) in organic high tunnels on the N.C. A&T Farm and Small Farms Unit (SFU) of the Center for Environmental Farming Systems (CEFS) was included in the tours of Small Farms Field Day and SFU Demonstration Day.

Working with CEFS, an organic blueberry pruning webinar was offered to 23 participants in March. N.C. A&T's horticulture specialist presented organic agriculture challenges and opportunities at the Small Farm Leadership 360 Initiative in Charlotte in June, which reached 44 future leaders in sustainable agriculture. The specialist also presented low tunnel strawberry work at the International Horticulture Congress in France in August, with over 125 horticultural professionals in attendance. These activities provided direct learning opportunities for small farms, Extension educators, and other agricultural professionals in organic and sustainable agriculture.

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

In 2022, there were a total of 876 participants reached for a total of 89 hours across 22 different interactions.

The ANR agent in Vance County assisted home gardeners with utilizing pollinators to produce safe gardens by conducting an organic gardening meeting. Seven gardeners attended the meeting. The gardeners were from Bear Pond, Watkins, Middleburg, and Henderson communities. The agent also consulted with these gardeners through garden visits, phone calls, and emails, providing them with organic vegetable production and organic pesticide information. Weekly radio programs were conducted on WIZS radio on organic vegetable production. The seven gardeners stated in post-meeting evaluations that

their organic vegetable production knowledge had increased. All the gardeners said they would adopt N.C. A&T Cooperative Extension recommendations. The five gardeners surveyed in October stated that they had grown vegetables organically. The gardeners stated they had good production because of Cooperative Extension's assistance. The gardeners said they used fewer pesticides, making their gardens safer, and said they wanted more organic training from Cooperative Extension in 2023.

In Forsyth County, the ANR agent provided home gardeners with a hands-on blueberry pruning workshop to break down the intimidation factor of pruning blueberry bushes. Thirty participants attended this workshop. All participants indicated they grew at either a home garden or community garden. Of the workshop participants, 19 completed the survey and 15**%** of reported they are beginning home food production. Ninety-four percent of respondents indicated they gained knowledge, skills, and confidence related to fruit gardening pruning practices during the workshop, and 100**%** indicated they intend to apply the Extension-recommended best practices within the coming year in their own gardens.

The ANR agent in Avery County partnered with Riverside Elementary School as they received a grant to start a homesteading program. The agent assisted the school by building raised garden boxes and erecting a greenhouse. Educational gardening classes were started with students from each grade learning the basics of planning a garden, sowing vegetable seeds, and planting vegetable plants. Heirloom apple trees were planted, and blueberry plants will be added in the future. The students actively participated in maintaining the gardens by watering, weeding, and trellising plants as they grew. Many youth saw for the first time how much of the produce they see in grocery stores and on their plates grows. The students were introduced to growing various plants, including asparagus, spinach, kale, beans, tomatoes, and pumpkins.

The ANR agent in Watauga County responded to a request to place and monitor traps for diamondback moths and pickle worm moths to monitor the phenology of these pests. The agent set traps at two proximate small farms that were growing suitable crops for such monitoring and diversifying into new crops along with new market sales outlets. They required frequent assistance with pest scouting and management questions. These farms were visited weekly from June through October. The data collection visits became ongoing technical assistance opportunities, with each agent being available regularly. At Full Moon Farm (site of the diamondback moth traps), the weekly visits facilitated early detection of soil drainage problems affecting a beet crop in high tunnels, Alternaria and fertility problems in a high tunnel celery crop, and Alternaria problems on green onions. Suitable integrated pest management recommendations combining succession harvests, better water management, crop rotations, and organic spray materials were developed and implemented with Full Moon's farmers to counteract these problems before they could significantly damage the crop. The combined value of these crops exceeded $5,000. At Simply Growing Farm (site of the pickle worm moth traps), Extension's regular consultations helped its growers expand production for Ashe County Farmers Market sales by assisting with managing weeds and improving sour gherkin and cherry tomato harvests. The farm reported a 30**%** growth in sales between the 2021 and 2022 seasons.

Overall, small, limited-resources farmers benefited from this program by applying learned technology in their organic and sustainable farming or switching to organic production. Extension agents benefited from the scholarship opportunities and our applied research and demonstrations, learned new organic and sustainable agriculture tactics, and thus were better able to serve their clientele.

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

The broader public had the chance to participate in our field days and learn how (organic) vegetables are produced. Organic products are grown without synthetic chemicals, while sustainable products are produced with fewer synthetic chemical inputs, reducing public concerns about pesticide residues in fresh fruit and vegetables.

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 paused the Tomato Organic Management and Improvement project because the team leader (Purdue University) decided to boost breeding efforts before conducting further on-station and on-farm trials. Results were disseminated through workshops, field days, conferences, and Extension and research publications. We will continue the organic tomato project and

enhance the SARE program because of the additional incoming funds from Southern Region SARE for professional development.

Peer-reviewed publications:

- Hoagland, L., Bloomquist, M., Carvallo, A., Colley, M., Davis, J. M., Davis, J., Dawson, J., Egel, D., Formiga, A., Fulk, F., Gu, S., Jaiswal, A., McCluskey, C., Mengiste, T., Myers, J. R., Richardville, K., Qu, L., & Zystro, J. (2022). The Tomi Project: Leveraging Beneficial Microbiomes and Farmer Partnerships to Prevent Disease in Organically Grown Tomatoes. *HortScience 57*(9).

- Gu, S. & Rana, T. S. (2022). Resource Allocations of Organic Day-neutral Strawberries in High Tunnels. *Acta Hortic*. (in press).

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.

Organic and sustainable farming practices help small, limited-resource farmers improve the health of their farmland, help them make more profits, and improve the quality of their communities. Several Extension programs aimed to introduce farmers to these practices and help them tap into the local food movement, which gives small and limited-resource farmers opportunities to transition conventional production into organic and sustainable production. The Diverse Native Hedgerow for Pollinators teaches small farmers to plant overlapping blooms to provide nector and shelter for pollinators. The results of a demonstration project were presented at a workshop with 55 attendees. Farmers had the opportunity to attend webinars on organic blueberry pruning and low tunnel strawberry production as well as a number of field days on organic crop production and organic gardening. Extension also sent 29 agents to the Carolinas Farm Stewards Association's Sustainable Agriculture Conference.

Annual Result: 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 specialty crops such as vegetables, herbs, and small fruits. These challenges often lead to less desirable economic returns from their farming operations. Low-tech, low-input season extension tools such as high tunnels are proven effective in helping small farmers extend their growing, harvesting, and marketing seasons, and increasing their profitability. The improved profitability will ultimately improve their quality of life.

Microgreens are a great way to address questions regarding gardening options for individuals with limited space and offer crop options for season extension into the harsher winter months when low outdoor temperatures are unfavorable or uncomfortable, and growing space is limited. Microgreens are a quick, low-cost, low-space, and therefore a low barrier entryway to gardening year-round inside or outside.

As an example, High tunnel construction is increasing in Vance County, but small farmers lack knowledge about vegetable production in these unique environments. The growing environment within a high tunnel is different from traditional field production (Sustainable Agriculture Research & Education). Thus, small farmers need assistance with vegetable production using high tunnels.

In 2019 the USDA Division of Economic and Research Services reported tomatoes as one of the most commonly consumed vegetables in the U.S. Throughout 2022 Stokes County Cooperative Extension experienced a notable increase in questions, with 15 producers reaching out regarding tomato production and management. The questions showed there was a need to address educational knowledge about tomato production and management.

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 2022, demonstration and applied research projects were conducted with warm-season vegetables, including tomato, bell pepper, eggplant, melon, watermelon, and ginger, and cool-/cold-season vegetables, including bok choy, lettuce, carrots, and garlic. These crops were grown in seven high tunnels on the N.C. A&T University Farm and in two high tunnels at the Small

Farm Unit (SFU) of the Center for Environmental Farming Systems (CEFS). Yield and produce quality data were collected, and the results were summarized and shared with farmers, Extension agents, and other horticultural professionals. We also continued distributing the High Tunnel Farming publication as farmers, Extension educators, and other agricultural professionals requested. All 1,000 copies were utilized by December, and a request for a second printing was made before the winter break.

Some selected activities include:

- Site visits by farmers, Extension professionals, students, legislators, and the public: 1,552 on the N.C. A&T Farm, Approximately 117 at the SFU.

- Three presentations at the Southern Region American Society for Horticultural Science (ASHS Conference in New Orleans in February. 80 horticultural professionals attended.

- One presentation on high tunnel soil health and management at the Educational Forum of the 2022 Small Farms Week (Zoom) in March with 75 participants.

- A presentation on Low tunnel strawberry production at the 1890 Association of Research Directors (ARD) Symposium in Atlanta in April. Approximately 50 agricultural professionals attended.

- Presented a program on maximizing high tunnel production at the Franklin County High Tunnel Program in May with 35 participants.

- Conducted a Small Farms Field Day in June with 237 attendees.

- Presented a high tunnel ginger production session at the Growing Ginger Workshop in Franklin County in July, with 35 participants.

- Showcased high tunnel crops during the Small Farms Unit (SFU) Demonstration Day at the Center for Environmental Farming Systems in July with 117 attendees.

- Displayed the High Tunnel Farming publication and presented on the N.C. A&T hemp program, including high tunnel hemp, at the Association for Extension Administrators (AEA) conference in Orlando in August, with 75 participants.

- Presented hoop house/high tunnels information at the Small Farm Leadership 360 Initiative in October with 42 participants.

- Presented an organic high tunnels course for Natural Resources Conservation Service (NRCS) employees (Zoom) in October, with 65 participant conservationists.

- Posted the video of the high tunnel crop demonstration at SFU in October: https://drive.google.com/file/d/1aZXR2Dsr5q3_qn4ZRYcKpX_cVts8ZDNz/view.

- Made two presentations (high tunnel basics and high tunnel ginger) at the Northeast NC Niche Agriculture Conference in November, with 111 attendees.

- Facilitated a presentation on winter high tunnel vegetables at the Southeast Vegetable and Fruit Expo in November with 55 participants.

Demonstrations, presentations, field days, workshops, and conferences offered effective learning opportunities for farmers and Extension educators in specialty crop production.

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

In 2022, small, limited-resource farmers benefited by adopting learned technology in their farming. Extension educators benefited by being equipped with the latest research-based information and technology that helped the audiences they serve. The results of the Small Farms Field Day (237 participants: 61% Black, 29% White, 4% American India/Alaska Native, 2.7% Asian) show that 92% of participants increased their knowledge; 65% of the 237 participants did not have a high tunnel, and 58.3% plan to install a high tunnel on their farm after attending the field day.

In the winter and spring of 2022, 63 individuals received training and hands-on practice in small-scale microgreen production by the ANR agent in Forsyth County. Each participant prepared and sowed a tray of microgreens and saw it through to harvest 2-3 weeks later. One-third of the workshop participants expressed interest in growing microgreens as a farm commodity. The remaining participants were growing at a home garden scale. Sixty-two percent of workshop participants completed a post-workshop survey, and 92% indicated that they gained skills, knowledge, and confidence about small-scale microgreen gardening. Qualitative responses indicated an intention to continue experimenting with other microgreen varieties. Similar training to these will continue in 2023 to meet the growing interest in small-scale and indoor gardening options in Forsyth County, where a sizable portion of the population lives in urban environments with limited growing space.

The Columbus County ANR technician assisted with installation and operational techniques for a season extension high tunnel unit. They visited the landowner's farm and surveyed the intended area. Design types of high tunnels were discussed according to the client's questions, allowing them to conclude their choice of the unit to purchase. Elevations were provided according to the markers in the area for erecting the high tunnel. Soil samples were taken in the intended growing area. High tunnel growing techniques, irrigation, and nutrient application were introduced.. A source of clean water was needed per recommendation. When the unit was delivered, the ANR technician assisted with package inspection to ensure all parts were supplied and helped with tunnel erection and plastic installation. N.C. A&T Cooperative Extension assistance provided the client with an experienced, high tunnel construction technician, volunteer support, and money-saving construction additions for better unit performance during operation. With no cost of construction time and volunteer time being free, the client gained value by keeping installation costs for the unit to $4,200.

The ANR agent in Vance County responded to a request to assist small farmers with vegetable production in high tunnels. The agent held a High Tunnel Vegetable Production meeting with six producers attending. The agent also conducted consultations with high tunnel producers through farm visits, phone calls, and emails. These producers were from the Townsville, Middleburg, Bear Pond, and Henderson communities. The agent partnered with WIZS radio to conduct radio programs on high-tunnel vegetable production. The six farmers stated in their post-meeting evaluations that they increased their knowledge of high-tunnel vegetable production and would adopt N.C. A&T Cooperative Extensions' recommendations. The five producers interviewed in November stated they successfully grew vegetables in their high tunnels. They also said they want more high tunnel education from Cooperative Extension in 2023.

Julius Griffin began Jewels of Health farm on his family's land three years ago. He made significant progress implementing several practices such as high tunnel production/ plastic mulch and producing unique high-profit crops like ginger, hemp, and orange/ yellow watermelons. Julius saw an opportunity to take his operation to the next level by turning his yellow and orange watermelons into a value-added product: bottled juice. Julius needed help achieving this goal. The ANR agent in Franklin County provided horticultural expertise regarding his greenhouse and raising watermelons. Once the watermelons were produced and he began building his juicing and bottling facility, the Family and Consumer Sciences (FCS), agent provided information on bottling regulations and getting the kitchen certified. Cooperative Extension also connected him to Operation Spring Plant, which provided funding for a water pump. Additional technical assistance was provided to help finish his kitchen and to show him how important a sand filtration system is when pumping from a surface water source. Julius produced his first batch of orange watermelon juice and has been selling it at $10 a bottle directly to consumers at farmers' markets and through restaurants.

The ANR agent in Stokes County partnered with the regional Extension specialist to develop an educational program to address questions and issues from tomato growers. During the two-hour tomato training, they reviewed the 2022 growing season and discussed preparation for the 2023 tomato season. Producers were informed about tomato varieties, insects, and disease diagnoses. Fifteen individuals with different backgrounds and production practices attended the training. s. Evaluations indicated that 100% of participants would change how they purchase or grow tomatoes, 93% would follow pesticide label instructions, and 93% could apply disease diagnostic techniques. Additionally, as a result of this program, 93% of individuals learned a new production technique and felt confident about implementing the knowledge gained from the workshop for future tomato production. With the knowledge gained, the producers can share production information with other producers to improve tomato health. Also, individuals are more equipped to handle purchasing tomato plants and seeds and to identify insects and diseases in their tomatoes.

Two sisters own 28 acres of land in Bladen County, which was being rented to another farmer but had been deeded to them from their late father, who had previously farmed. The sisters were looking for opportunities to develop the farm. They have always wanted to grow different types of herbs to prepare healthy foods targeting the ethnic groups in the community who desire to prepare their foods with herbs from their home countries. The sisters attended a series of workshops called Developing Personal Risk Management. The series consisted of seven Zoom sessions and one in-person workshop. The workshops were held with Digital Extension Risk Management Education and National Crop Insurance Services. They completed the homework assignments after each workshop, including an inventory assessment of the resources owned and controlled by the farm. Using enterprise budgets, they calculated their break-even costs and outputs. After the workshop, they completed a risk management and marketing plan. One of the actions on the project was to purchase a high tunnel and have it installed. While networking at one of the educational sessions, the sisters were made aware of the USDA-NRCS EQUIP Cost Share Program, which helps lower the costs of purchasing a high-tunnel greenhouse. They were approved to receive a cost share grant valued at $7,800. They completed the construction of the high tunnel in October and will be able to harvest their first crops in January 2023. By completing all of the actions listed on their risk management and marketing plans, they will have the tools and the confidence they need to deal with future risks and opportunities, all due to working with the ANR agent in Bladen County.

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

Specialty crops are essential, nutritious, and flavorful components of a healthy diet. They provide essential nutrients such as sugar, protein, minerals, digestible fiber, vitamins, and antioxidants. A high tunnel is an inexpensive option to prolong vegetable crops' growing and marketing seasons with increased yield and enhanced product quality. Therefore, the broad public will benefit from the extended supplies of locally produced and nutritious vegetables and fruits 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.

Results were disseminated through workshops, field days, conferences, and Extension and research publications. Projects continue in 2023 but with focused crop demonstrations of ginger, garlic, cool-season vegetables, and cherry tomatoes.

Peer-reviewed abstracts and publications:

- Fulk, R. & Gu, S. (2022). NC A&T Plasticulture Publications and Resources for Small Farmers. HortScience, 57(9) S237.

- Gu, S., Coffey, P., Kimes, J., & Moffitt, Q. (2022). Yield and Fruit Quality of 12 Cherry Tomato Cultivars in High Tunnels. HortScience 57(9) S263.

- Moore, D. N. and Gu, S. 2022. Eggplant. In “Vegetable Cultivar Descriptions for North America List 28”, edited by Mou B. HortScience 57(8)985-989. https://doi.org/10.21273/HORTSCI.57.8.949.

- Sanjun Gu. (2022). High Tunnels, High Profits: Extension Specialist Unlocks the Potential of Plants, Plastic and Sunshine. Re:Search Vol 19: 20-23.

- Sanjun Gu. Use of Tunnel systems. In "2022 Regional Strawberry Production Guide" ed. M. Hoofman, A. McWhirt and J. Samtani. North Carolina State University. (in press).

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.

Low-tech, low-input season extension tools such as high tunnels are proven effective in helping small farmers extend their growing, harvesting, and marketing seasons, and increasing their profitability. Growing in a high tunnel environment is different from growing in fields, and Extension at A&T grows warm weather vegetable and fruit crops in seven high tunnels at the University Farm and two at the Small Farm Unit of the Center for Environmental Farming Systems. Yield and produce quality data were collected, and the results were summarized and shared with farmers, Extension agents, and other horticultural professionals through field days, presentations, and educational events. Farmers learned about growing specialty crops, such as microgreens and ginger, in high tunnels and received instruction in high tunnel construction and maintenance, growing techniques, irrigation, and nutrient application. The new crops and season extension through high tunnels means new markets, a longer growing season, and increased profitability for small farmers.

Critical Issue

Protecting Environmental and Natural Resources

Adapting microbial enzymes to capture atmospheric carbon and increase biofuel crop yields

Project Director
Robert Rose
Organization
North Carolina State University
Accession Number
7000561

ANNUAL RESULT:Adapting microbial enzymes to capture atmospheric carbon and increase biofuel crop yields

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

Our work addresses the problem of increased atmospheric carbon dioxide, the most abundant greenhouse gas. Carbon dioxide is being released from the industrial use of petroleum products, which had been stored by previous living organisms. We are developing an alternative carbon dioxide-fixing cycle that could increase carbon fixation by plants.

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 activities:

The alternative carbon-fixing cycle that we are studying is called the synthetic rTCA (reductive Tricarboxylic Acid) cycle. It could potentially increase growth rates of biofuel crops and food crops which are limited by available carbon. This project is in collaboration with Amy Grunden in the Plant and Microbial Biology Department. Dr. Grunden developed the synthetic rTCA cycle, utilizing five enzymes that were collected from different organisms. The original study through the DOE demonstrated the cycle functioned in a test tube, and in a pilot study in the plant *Camelina sativa*. Now we want to optimize the enzymes of the cycle to make it function more efficiently. Our first two aims are to modify two of these enzymes that were derived from thermophilic organisms, bacteria that live at 80-90 °C. The enzymes from these organisms and are not very active at ambient plant temperatures. Our goal is to identify mutations in these enzymes that will increase their activity at room temperature. If we can devise a general strategy to accomplish this, then there are many more thermophilic enzymes that catalyze useful chemistries that we could modify for applications in the growing biofuel and biomaterial industry.

The two enzymes that we are currently working with are: 2-oxoglutarate carboxylase (OGC) and oxalosuccinate reductase (OSR). Over the past year we have made progress developing the techniques and reagents that will allow us to screen mutations to decrease the temperature of activity of these enzymes.

1) Engineer a mesophilic OGC:

OGC is a member of the important biotin dependent carboxylase family that uses biotin, or vitamin B7, as a cofactor. Several members of this family function in normal metabolism in all organisms, and this family of enzymes is one reason we need dietary biotin. OGC is a unique member of this family only found in thermophilic organisms that grow in hot springs or deep ocean hydrothermal vents. OGC uses ATP to capture carbon dioxide dissolved in water (in the form of bicarbonate) and transfers it to the metabolite 2-oxoglutarate. The enzyme is composed of 3 domains. Until recently we have been working with the first domain, the biotin carboxylase domain, which binds the bicarbonate and ATP and transfers the carbon dioxide to biotin. This year we made progress in analyzing the activity of this domain and the full-length OGC.

Based on our previous work, we derived some educated guesses about mutations in the biotin carboxylase domain that might increase activity at lower temperatures. This year we developed a high throughput assay to allow us to test these mutations. The assay can be carried out in a 96-well plate and measured on a plate reader. We have also shown that we can measure activity from a cell extract with a one step purification. We propose that this will be doable in a 96-well plate format. We plan to introduce mutations using a PCR-based random mutagenesis protocol, which will allow us to introduce and test about 100 mutations at a time.

We have also made progress in purifying and analyzing the full length OGC protein. This complex contains 2-4 copies of each of the three OGC domains. We showed that the OGC complex has enzymatic activity and we have begun efforts to crystallize the complex to determine its structure. There is currently no structure of the OGC complex, and this structure would be invaluable for understanding how the enzyme functions. By analyzing the complex, we realized that it is coming apart at lower concentrations. We believe that the complex might be more stable in the presence of substrates, which we are now testing.

2) Engineer a mesophilic oxalosuccinate reductase, OSR:

OSR is the next enzyme in the synthetic rTCA cycle and is needed to measure the activity of OGC. That's because the product of OGC, which is oxalosuccinate, is unstable. We have purified OSR and shown that it is active by itself. We combined it with OGC to measure OGC activity. This introduces the possibility of measuring the temperature of activity of OSR and deriving mutations to decrease the temperature of activity.

3) Model the activity of the synthetic reverse TCA cycle *in vitro* in order to optimize the overall cycle.

We have started a collaboration with Cranos Williams from the Department of Electrical and Computer Engineering to model the synthetic rTCA cycle. A preliminary model will become part of an NSF grant that we are writing.

4) Localize the enzymes of the synthetic rTCA cycle to maximize flux through the pathway.

This is a future goal, once we have optimized the component enzyme activities.

5) Increase the diversity of the Master's program in the College of Agriculture and Life Sciences (CALS) through an NSF-funded training grant.

This project is based on an NSF training grant with an original end date of February 28, 2021. The NSF recently been granted us a second No Cost Extension and we are recruiting students for the coming 2023-2024 academic year. Students are recruited mostly from colleges in North Carolina. Over the past 5 years we have assisted 15 low-income students of diverse backgrounds to obtain a Masters degree. Graduates of the program have found good jobs in industry. Three of our graduates are continuing in a PhD program, and one graduate is attending medical school. Last year we were not successful in recruiting students, partly due to the fallout of the Covid19 pandemic and the changing economy. Our goal for the coming year is to recruit 5 students.

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

The immediate audience of our current research is the research community interested in developing biotechnological strategies to reduce atmospheric CO2 and to enhance biofuel production. I have organized an "interest group" on strategies to develop biofuel and biomaterial at the upcoming ASBMB meeting, the largest Biochemistry meeting in the country. The title of the workshop is: Engineering enzymes and microorganisms to replace petroleum products with renewable biofuels and biomaterials. The meeting will be held in Seattle on March 25-28, 2023.

This project has also benefited undergraduate students in the Biochemistry Department at NCSU. Over the past year I have worked with three undergraduates in the lab.

The audience for the Biochemistry Masters program are students in local North Carolina colleges who are looking for opportunities to continue their education. The low-income students who join the program have benefited significantly from the program. Many of them would not have continued in graduate school without funding, since low-income students are often reluctant to go into debt. We have also increased the diversity of the graduate programs in the College of Agriculture and Life Sciences. The graduate programs are not as diverse as the undergraduate programs at NCSU. A more diverse student body will make the College more attractive for future graduate students. Students graduating from the program have found good jobs in industry, also increasing the diversity of the local biotechnology companies.

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

The broader public benefited from the Biochemistry Masters program through diversifying the biotech workforce. Two students graduated in 2022. One of these students is working in a biotech company in Research Triangle Park. The other student currently has a job with Duke Energy.

The results of the carbon fixation project will eventually benefit society once it has been developed by reducing greenhouse emissions.

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.

There are two ways that my thinking has developed over the past year:

1) I plan to incorporate cryo-EM more broadly in my approach. In the past I have focused my efforts on protein crystallography to analyze the structures of our proteins. Single-particle cryo-EM is a newer technique with some advantages. Cryo-EM is a microscopy technique that requires taking images of thousands to millions of particles and averaging them together to get high-resolution structures. One advantage is that cryo-EM will allow us to determine structures from samples at high temperatures, in which our enzymes are most active. This might provide valuable information about enzyme dynamics. Also, cryo-EM doesn't require crystallization, which will allow us to determine structural information even if the protein is flexible. Do follow up with this idea, II will collaborate with the cryo-EM facility at NIEHS.

2) I have started a collaboration with Rafael Guerrero whose expertise is in bioinformatics. We are investigating an approach described in a recent paper: Pinney, M. M., et al (2021) Parallel molecular mechanisms for enzyme temperature adaptation, *Science 371*. In this paper the authors claimed to be able to identify residues in an alignment of 1,000 different sequences that distinguish related thermophilic and mesophilic enzymes. The idea is that there is enough information within the huge amount of sequence data that has been collected to extract this information. That would helps us determine which amino acids were most important to mutate to change the temperature of activity. I am working with Dr. Guerrero to test this idea for our thermophilic enzymes.

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.

LAID GROUNDWORK FOR SPECIALIZED PLANT BREEDING TO REDUCE ATMOSPHERIC CARBON DIOXIDE: Carbon dioxide released by industrial use of petroleum products is among the greatest contributors to global warming and to the growing climate threats it poses. To help reduce the environmental impact of carbon dioxide in the atmosphere, NC State researchers are developing a method to enhance plants' natural ability to pull carbon dioxide from the environment and convert it into nutrients. In addition to benefiting the environment, this method could increase the growth of biofuel and food crops. Researchers have developed a highly efficient method for testing the effects of various mutations on carbon processing in plants, which will allow them to introduce and test about 100 mutations at a time. They have shared the results of their research through a specialized interest group on strategies for developing biofuel and biomaterials, workshops, and graduate and undergraduate student training.

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

Delete

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.

x

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

x

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

x

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.

x

Environmental and Natural Resources

Project Director
Meredith Weinstein
Organization
North Carolina State University
Accession Number
7000168

Annual Result:Environmental and Natural Resources

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. Between July 2021 and July 2022, NC had the 3rd highest rate of growth, adding 133,088 residents (a growth rate of 1.3%). Population growth and associated sprawling development contribute to 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 put into practice.

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 specialists used applied research to develop innovative products, technology, and research-based best management practices (BMPs) to protect forests, water, soil, air, and other natural resources. Extension specialists and agents delivered information on these innovations and practices and promoted the adoption of BMPs through Extension publications, websites, meetings, workshops, seminars/webinars, videos, newsletters, consultations, community and demonstration projects, certification programs, and public outreach efforts.

- NC State Extension agents used **social media and mass media** to provide new environmental and natural resource educational information reaching over 2 million individuals through mass media such as television, radio, and newspapers and another 150,000 individuals through social media and website posts.

- Environmental and natural resource topics were presented to 12,000 individuals who attended **training** provided by Extension agents and to an additional 18,000 individuals who attended training provided by Extension specialists.

- A newly formed team of Extension specialists and agents began development of a new **Water Resources web portal** to share information and resources on topics ranging from agricultural irrigation and wells to community stormwater and wastewater to ponds, streambank repair, and everything in-between.

Extension in Transylvania County worked with Conserving Carolina, AmeriCorps, and a variety of other community partners to host the sixth annual **Riverfest**. Approximately 800 local residents attended the event, enjoying live music, food, and engagement with a huge diversity of community partners committed to environmental education. Attendees learned about stream invertebrates, rain gardens, local bird populations, water quality, historical and current industrial water use, and much more. **NC State Extension's streambank repair efforts and public engagement sustain the quality and diversity of North Carolina's natural resources by protecting drinking water, increasing property values, spreading awareness of the importance of healthy waterways, and protecting recreational spaces for all North Carolinians to enjoy.**

Odor and pollutant emissions from livestock barns can cause conflicts between livestock producers and neighbors and can thus affect the sustainability of NC livestock production. Funding from USDA-NRCS allowed us to develop the **engineered windbreak wall-vegetative filter strip system**, a low-cost, retrofittable system that reduced odor emissions from livestock barns by up to 80%. Funding obtained from the NC Dept. of Justice to **build, monitor, and demonstrate the system on a broiler house** as well as **monitor and demonstrate the existing system on the swine farm**. Based on the data that we collected, in 2022, a full-day event was organized to make policymakers, producers, and integrators aware of the potential of this system in reducing emissions. The event, which also covered other aspects (e.g., waste management and renewable energy), was attended by 34 participants.

New Hanover County Extension, in partnership with the New Hanover County Arboretum, provided education and tours of a broad range of water quality and sustainability models, including a **rain garden, infiltration zone, cistern, permeable pavement, and a constructed wetland/bog garden**. In 2022, 150 residents and professionals were educated using these models, which have eliminated runoff into Bradley Creek. As a result of these efforts, Extension received the **Lower Cape Fear Stewardship Development Award for Outstanding Stewardship.**

NC State Extension agents offered a variety of **programs** addressing issues related to environmental protection. As a result of this programming, 13,696 participants demonstrated increased knowledge of climate mitigation practices, and 3,677 participants expressed a willingness to adopt 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.**

To protect North Carolina's forests, **NC State Extension's Forestry** program worked with multi-state partners to develop an **online course in prescribed fire** (controlled burning for forest management), teaching more than 570 individuals from around the world how to safely apply this technique to ensure that the millions of acres they own or manage remain healthy, vibrant ecosystems. Extension's Forestry program also educated more than 95,901 landowners, land managers, and other community members across the Southern US about the importance of prescribed fire in forest management, and 37 landowners and professionals learned practical skills to better protect the forests around their homes from wildfires.

Extension Forestry collaborated with multiple partners, including ForestHer NC, to put on multiple **in-person and online women-focused forestry education events** across Virginia and NC, including a chainsaw safety course and a women-in-fire training exchange. Post-event survey results from the chainsaw workshop indicate that 100% of respondents increased their knowledge on a variety of topics related to chainsaw use and safety. A 2-week fire training event for female fire practitioners resulted in more than 50 participants from around the world increasing their awareness, knowledge, and leadership skills in this key aspect of forest management.

To replace damaged trees in the wake of severe weather events and ensure that tree populations continue to absorb stormwater runoff, reduce heat impacts, filter nutrients, build soil, and provide numerous environmental benefits to local communities, Extension in New Hanover County continued hosting the annual **TreeFest** event. With the support of many partners and sponsors, including the NC Forest Service and the Alliance for Cape Fear Trees, TreeFest 2022 gave away 5,500 bare root tree seedlings of diverse species to a total of 884 households. Extension staff also provided **technical guidance** on tree selection and **best management practices** for tree planting and care.

Forestry programs in 2022 increased the knowledge of approximately 115 Extension agents and agency partners on forest health through 3 workshops in the Carolinas. Extension Forestry also continued to conduct forest health programming to increase knowledge of invasive species, with efforts including 14 educational events, development of 20 Extension factsheets and articles, 30 media pieces, 41 social media posts, and delivery of over 600 native trees to replace invasive Bradford pear trees. These outreach efforts helped over 235,000 people increase their awareness of the impact of invasive species on local forests. **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.**

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

In 2022, Extension supported and led efforts to counteract the environmental effects of extreme rainfall, reduce stormwater runoff pollution from growing communities, and support urban sustainability and water quality. Wake County Extension trained and certified 5,465 individuals, including over 20 HOAs, in **stormwater control measure inspection and maintenance**. Of the over 350 stormwater professionals certified each year in Extension workshops, over 95% report that the design, function, maintenance, and water quality protection effectiveness of their stormwater practices have improved as a result of their participation. Statewide, Cooperative Extension trained and certified 4,379 people in stormwater control measure inspection and maintenance. In addition, 18,504 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.**

Efforts of NC State Extension enhanced the quality and diversity of North Carolina's natural resources by conserving and protecting the environment and mitigating climate change. To address the growing need for qualified stormwater management installers in residential communities, Cooperative Extension presented a **Rain Garden and Water Quality Certification Workshop** in partnership with the Town of Sunset Beach; 30 participants received 3 hours of classroom training, followed by hands-on installation of a rain garden at the town hall. After the workshop, 22 people tested for and received Rain Garden and Water Quality Certification through NC State. In addition, the Town of Sunset Beach has installed a land commercial-sized rain garden that will capture and treat stormwater runoff from the newly built town hall. **In addition to protecting local water quality, this rain garden will provide a demonstration site to educate residents on stormwater BMPs.**

Stormwater wet ponds are among the primary means of stormwater control in most residential and commercial developments. Warm weather and nutrient runoff can combine to cause explosive growth of aquatic weeds, blocking storm drains, exacerbating flooding, preventing recreational water use, killing fish, and causing many other environmental problems. To help ensure proper aquatic weed control, Extension implemented a **comprehensive education and technical assistance program** to assist professional landscapers and residents in the Cape Fear region. This program included **site visits** to stormwater ponds to provide technical assistance, **online classes** for Extension Master Gardeners and Extension Agents on aquatic weed identification and management, and **aquatic weed pesticide training** through the NCDA&CS. In 2022, 10 pond site visits were conducted through this program, and 29 residents, HOA officials, and landscapers were provided with technical advice. A regional Aquatic Weed Management and ID meeting was held for 35 Extension Master Gardener Volunteers and Horticulture Agents, and a 3-hour continuing education credit class on aquatic weed management and identification was provided to 11 local participants, 8 of whom received continuing education credits for NCDA Pesticide Licensing. These programs fulfill a critical need for expert stormwater pond management. **NC State Extension's trusted research-based technical assistance provided solutions to stormwater runoff problems, and as the leader in experiential education, Extension is providing opportunities for students to put learning into practice.**

NC State Extension collaborated with environmental advocacy groups and local and state government to provide online and hands-on certification workshops in areas impacted by streambank loss to reduce sedimentation and prevent nitrogen and phosphorus from entering streams and drinking water supplies. In 2022, 5 **streambank repair workshops** were held across the state with local partners, coordinating the efforts of over 259 participants to repair over 1,000 linear feet of streambanks during workshops. Surveys of local partners indicate that an additional 6,025 feet were repaired outside workshops. Streambank repairs installed since 2019 will reduce soil loss by 1,187 tons per year and prevent 1,865 tons of nitrogen and 1,831 pounds of phosphorus from entering waterways annually. In addition, a survey of realtors and property appraisers estimated that stabilizing and repairing streams increased property values by an estimated $3,300,000.

Recent extreme events have revealed the vulnerability of the transportation system to flooding. Fully functioning transportation infrastructure is crucial to emergency response, commerce, and community functions. These incidents are likely to increase with climate change. It is important to predict where washouts are likely to occur prior to an extreme rainfall event so that safety alerts can be issued. Extension and NC State researchers partnered with a team from NC Sea Grant to develop and evaluate a method for identifying road crossings that are likely to be submerged or washed out during extreme weather events. This method is currently being tested in 3 NC watersheds, and it is being used to identify and develop upgrade **plans for routes resilient** to extreme rainfall, which can provide transportation pathways during or immediately after extreme flooding events. These efforts are paving the way to help NC DOT prioritize route upgrades so that commercial and residential drivers can have safe routes of travel, even during extreme events such as hurricanes.

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 2022, these systems collected more than 1 million data points, including data on pH, temperature, algae populations, and concentrations of bacteria that are potentially hazardous to humans. Data summaries posted to the CAAE's website provided 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.**

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

NC State Extension provides content coordination for the **National Pesticide Environmental Stewardship website**, providing access to information on proper pesticide handling. The site receives an average of 15,000 hits/month and is supported by the Center for IPM at NCSU. The site houses the National Pesticide Safety Education Month website. In addition, NC State Extension manages and hosts the **Pesticide Safety Education Program Improvement and Modernization Initiative (PSEP-IMI)** Resources Website, a national repository of over 930 Land Grant University pesticide safety education resources created by pesticide safety educators or partners in affiliated programs at Land Grant Universities. A major goal of the PSEP-IMI is to strengthen Pesticide Safety Education Programs by improving the quality, consistency, and accessibility of applicator training materials and classes, as well as passing rates and scores on certification tests. This website helps achieve this goal by expanding the availability of educational resources to educators affiliated with Pesticide Safety Education Programs at Land Grant Universities. The NC State Extension **Pesticide Safety Education** web portal contains 245 individual webpages, including a "toolkit" for county pesticide coordinators that includes electronic media, educational resources, and instructional materials. The portal had over 27,000 visitors in 2022. **Providing current pesticide safety information to pesticide safety educators is one way NC State Extension is protecting the environment for North Carolinians.**

In 2022, Extension offered more **Pesticide Schools** than in any other year. In partnership with the NCDA&CS, Extension Pesticide Schools served a total of 1,455 attendees, garnering overwhelmingly positive feedback. For a majority of attendees, the Pesticide School is their first exposure to NC Cooperative Extension, and the schools energize them to become more engaged in Extension programming. In addition to their use in Pesticide Schools, Extension Pesticide Safety Education Program training manuals are used for horticulture class curricula at 36 NC community colleges. To support compliance with pesticide regulations, Cooperative Extension in Alamance County offered 12 classes to farmers, landscapers, and other clients, allowing 348 pesticide applicators to receive license renewal credits. In Harnett County, 10 pesticide training events were offered to 80 private applicators, allowing them to save over $276,000 annually by applying their own pesticides. Pesticide Coordinators in Person, Granville, Vance, Wake, and Warren counties teamed up to provide in-person and Zoom-based training, ensuring that 219 attendees earned pesticide recertification credits. In Johnston County, Extension conducted 25 in-person training opportunities, providing pesticide safety recertification training to 158 private applicators, new pesticide safety training to 604 applicators, and fumigation training to 27 applicators. It is estimated that Johnston County growers saved over $450,000 by learning to apply their own pesticides, and this program was able to recertify 100% of the private

applicators seeking recertification. Statewide, 18,020 people attended over 1,850 hours of pesticide training that was delivered by Extension, including 15,734 pesticide applicators who received 6,842 continuing education and re-certification credits.

Providing effective, safe pest control within residential, institutional, and commercial buildings in NC is critical. As construction materials and techniques improve, they can actually create greater challenges in urban pest control, particularly control of subterranean termites, which cause an estimated $2 billion in damages annually in the US. To address the need for safe, effective termite control expertise in urban settings, Extension led the **NC Termite Technician Training Program** in partnership with NC State, NCDA&CS, and the NC Pest Management Association. This program provides both classroom and hands-on training in all aspects of proper inspection and treatment for termites and serves pest management professionals across the state. After completing the program, participants have a clear understanding of NC regulations, the construction elements that affect termite control measures, calculations associated with termite treatments, and how to conduct a termite inspection. **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 protect NC's natural resources, reduce hazards, and educate growers and the public about the importance of managing industrial and household waste, Extension led **trash pick-up, pesticide disposal, and pesticide container recycling initiatives** in 2022. In Nash County, Extension partnered with the NCDA&CS to hold a cost-free pesticide disposal day for farmers, safely disposing of 9,854 pounds of pesticides and 781 pesticide containers and saving growers $49,270 while helping them avoid disposal hazard liabilities. In Northampton County, Extension partnered with the county landfill to grind up 20,955 pounds of plastic from pesticide containers to be used in recycled products. McDowell County Extension continued its Keep McDowell Beautiful program in 2022, partnering with local government, community, and conservation organizations to coordinate 55 volunteers and 275 hours of service. These efforts removed 1,340 pounds of litter and debris from Lake James, improving water quality and discouraging future littering.

In Wake County, Extension upgraded the **Compost Lab at NC State**, installing 10 new compost bins, renovating existing composting areas, and setting up the worm barn to demonstrate 8 methods of composting using worms (vermicomposting). They also established 4 test plots to demonstrate the impact of varying levels of vermicompost application. During the **International Vermicomposting Conference**, over 150 attendees were able to view various methods of composting and vermicomposting to reduce organic materials going into landfills. The Compost Lab is now set up to offer training and demonstrations to the public, including schools, community gardeners, and professional composters. Given that just one home compost unit can divert 650 pounds of organic waste from the landfill, providing opportunities to teach composting techniques will continue to be vital to the protection of our environment. **NC State Extension's pesticide recycling and litter clean-up programs sustain the quality and diversity of North Carolina's natural resources by ensuring pollutants do not cause soil, groundwater, and surface water contamination.**

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 2022 to facilitate the use and transfer of new research-based knowledge:

- Agent Support Through the Water Resource Program Team
- Climate Resilient Practices...That Make Financial Sense
- County Extension Support Efforts for County Forest Landowner's Organizations
- Current Irrigation Topics in NC
- Deer Browse: Christmas Tree Research Implications for Other Crops

- Delivering Climate (Change) Insights for Extension
- Effectiveness of Agricultural Conservation Practices
- Innovative Stormwater Management Models
- Silvopasture Establishment and Management in NC
- Soil Health Management & Testing: Know-How for Sustainable Farming
- Staying Current with All Things Forestry

The following **Factsheets and Peer Reviewed Extension Publications** were developed by Extension specialists for dissemination of research-based information to Extension agents, growers, and other stakeholders.

The Educational Needs of North Carolina's Forest Landowners

Educational Needs: A Survey of the Urban Wood Drying Community

Identification of Common Trees of North Carolina

Elm Zigzag Sawfly

Twolined Chestnut Borer

Beech Bark Disease

Biological Control of Emerald Ash Borer in North Carolina

Diseases of Ash Trees in North Carolina

Diseases of Dogwood in North Carolina

Common Disease Pests of Maple in North Carolina

Common Disease Pests of Oak in North Carolina

Insect Pests of Dogwood in North Carolina

Common Insect Pests of Oak in North Carolina

Common Insect Pests of Maple in North Carolina

Common Insect Pests of Ash in North Carolina

Callery Pear: 'Bradford' and Other Varieties and Their Invasive Progeny

Tree-of-heaven (Ailanthus)

What is Climate Smart Forestry? A Brief Overview

Zoning and Land Use Regulation of Forestry

Practicing Forestry Under Local Regulations

Let's Work Together in Addressing Environmental and Societal Issues: Guide to Engaging Stakeholders and Communities

Biochar Production through Slow Pyrolysis of Animal Manure

How Does Nitrogen Move Through a Swine Farm with a Lagoon-Sprayfield System?

Nowcasting and Forecasting Coliform Bacteria Contamination in Coastal Systems

Road Map to the Worker Protection Standard for Agricultural Pesticides

Mapa de la Ley de Protección al Trabajador para Pesticidias Agrícolas

Composting at NC Residential and Summer Camps

Manage Compost and Soil Contaminated with Broadleaf Herbicides in Residential, School, and Community Gardens

Managing Backyards and Other Urban Habitats for Birds

Reptiles and Amphibians in Your Backyard

Dairy Manure as a Fertilizer Source

Best Management Practices for Agricultural Nutrients

Soil Acidity and Liming for Agricultural Soils

Careful Soil Sampling—The Key to Reliable Soil Test Information

Muestrear el suelo cuidadosamente: la clave para obtener información confiable sobre el análisis de suelo

The Status and Trends of Wetland Loss and Legal Protection in North Carolina

Water Quality and Sprayer and Spreader Calibration

Water Quality and Professional Lawn Care

Water Quality and Commercial Lawn Care

Water Quality and Professional Turfgrass Managers

Irrigation Water Quality Problems

Extension specialists contributed to solving regional and national issues through **multi-state collaborative Extension efforts**. Some multi-state programs NC State Extension participated in include:

- SERA3 Collaborative Integrated Pest Management Workgroup
- SERA5 Sweetpotato Collaborators Conference
- SERA6 methodology, interpretation, and implementation of soil, plant, byproduct, and water analysis
- SERA17 phosphorus management
- NC1186 Water Management and Quality for Ornamental Crop Production and Health
- NE2203 Legal Issues in Agriculture and Natural Resources
- NCERA224 Extension and IPM for ornamental plants
- S1073 IPM and Biocontrol of pests on ornamental plants

- Tactical Science Coordination Network (TSN) to enhance food security and biosecurity in U.S. agricultural and food systems
- Forest Pest Management certification manual for 7 participating southeastern states
- Webinar with U GA on red imported fire ants
- With the University of MD on solar development and decommission
- Southern Extension Weed Science Working Group.
- Appalachian Beginning Forest Farmer Coalition webinars, hands-on workshops, website with videos and extension leaflets supporting the growing forest farming community involves researchers, extension personnel from PA, OH, VA, NC, WV, KY
- Mid-Atlantic Soil Testing and Plant Analysis Work Group develop, adapt, and update soil and plant testing methods for over a dozen states in the United States
- Fertilizer Recommendation Tool (FRST) initiative over 37 land-grant university faculty, the USDA-ARS, NRCS, and FSA
- Science and Technology for Phosphorus Sustainability NSF Center, a multi-state project that includes about 40 researchers
- Clemson Extension to develop a Stormwater & Stream Monitoring short course
- Pesticide Educational Resources Collaborative (PERC), EPA, UC-Davis Extension, Oregon State University, to coordinate the development of pesticide-related educational resources

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. 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.

delete

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

x

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.

x

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

x

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

x

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.

x

Improving agricultural water quality with on-farm ecological engineering techniques

Project Director
Niroj Aryal
Organization
North Carolina Agricultural and Technical State University
Accession Number
1023322

Improving agricultural water quality with on-farm ecological engineering techniques

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

The project addresses the water quality problem of farm pond that collects water from farm areas. More specifically, the runoff water from farm areas can contain pollutants including sediments, nutrients, agrochemicals, antibiotics, pathogens, and antibiotic resistant bacteria. Since the farm pond water is being used for irrigation of crops, accumulation of pollutants by crops and subsequent exposure can affect the human health. The project addresses the water quality and crop uptake of pollutant issues by utilizing ecological engineering techniques, wetlands and biofilters, to remove pollutants in farm pond water

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, the experimental setup for wetlands and woodchip bioreactors were completed and the data were collected. We evaluated pathogens removal by different types of woodchip reactors - reactors filled with woodchips only, filled with woodchips and copper metals, filled with woodchips and aluminum metals, and woodchips and alkalization stabilization. Additionally, we evaluated the removal of several pesticides by the woodchip bioreactors. For these analyses, we developed methods to analyze pathogens and pesticides.

Removal of glyphosate by two stage wetlands (surface followed by subsurface) was studied. Additionally, removal of several pesticides by the wetlands was studied.

Therefore, major achievements towards the evaluation of pollutant fate and removal in a two-stage wetlands and a woodchip bioreactors were made. We continue to develop methods for antibiotics and antimicrobial resistant genes. We also preliminarily conducted the study to evaluate the fate of the pollutants in vegetative systems.

Other activities included presentations, publication, outreach, undergraduate, graduate, and reseach associate training, and extension.

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

The project demonstrated high removal of pathogens in the runoff water by woodchip bioreactors and of glyphosate in the runoff water by dual-stage wetlands. The results are significant to engineer improved conservation practices by scientists and eningeers, and to protect farm ponds from harmful pollutants. These kinds of low-cost methods for treatment of polluted runoff are crucial for wider adoption and significantly improve farm pond water quality. The results were shared with scientific audiences and public through presentations made at conferences, and publications. Additionally, the project provided broad opportunities to two undergraduate and two graduate students at NCA&T to conduct research for their thesis and undergraduate research experience. Three of the four were underrepresented minority students.

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

The project team presented in the NC extension conference on the irrigation water and produce safety thus raising awareness of importance of clean water for production and handling of produce, and ways to improve farm pond water. Additionally, the project contributed to producing the next generation of scientists and engineers, particularly from underrepresented community by training them in research and science.

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.

Some of the challenges the project encountered included supply chain delays, personnel changes in the service laboratory, and difficulty hiring the research associate following the departure of previous research associate. Additionally, due to the lack of controlled growth space for growing vegetations have posed a challenge.

The project provided an opportunity for training of two undergraduate students, two graduate students, and a research associate during the period. The undergraduate students worked in their own independent research respectively in land application of wastewater and rainwater recycling. The graduate student worked each in wetlands and in biofilter components of the project. The research associate worked in the vegetated system component.

The results have been disseminated in extension conference, scientic conference of AEES (American Ecolgical Engineering Society), ARD Symposium, and the Next Generation Sustainable Technologies for Small-scale Producers conference. The project produced a total of 8 conference presentations, an under review paper, and a published review paper during the last reporting period.

The project team intends to continue to seek for research associate, expand the analytical methods, and conduct experiments for antibiotics removal and the fate in wetlands, biofilters, and vegetated systems.

Natural Resource and Environmental Systems

Project Director
Lauren Hargrave
Organization
North Carolina Agricultural and Technical State University
Accession Number
7001859

Annual Result: Soil Health

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

Current trends show that small-scale and limited-resource farms face critical farm resource management issues in North Carolina and the southern United States, especially under changing climates (i.e., hot weather, cold fronts, flash floods, droughts, winter storms, etc.). These farmers and landowners (having landholding of ~20 acres or less) generally do not realize the full benefit of their lands and how efficiently they can protect and manage their agriculture and natural resources (i.e., soil, water, air, etc.). Thus, they cannot compete with large-scale farms in exploring all the resources provided. Therefore, they need to follow regenerative and climate-resilient farming practices to improve their farm production while reducing their environmental footprint (i.e., protecting their soil, water, and 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.

Natural Resource Testing Kit for Soil Health Program (Statewide)

The agriculture and natural resource (ANR) specialist distributed 16 natural resource testing kits to Extension agents. The kits include an accessible measuring kit for soil pH, EC, irrigation, auger, clippers, GIS, video kit, temperature, conductivity, digital microscopes, and a comprehensive soil testing kit. They were prepared and distributed at Small Farms Week educational events hosted by N.C. A&T Cooperative Extension in March 2022. These kits helped agents in 14 counties (the service counties covered by Cooperative Extension at N.C. A&T) get trained in diagnosing rapid issues faced by farmers or landowners related to their farm resources, farm input, soil, water, and land environment. The Extension agents received training to ensure they were knowledgeable and confident in helping farmers when they visited a farm or received a phone call about problems related to their natural resources.

On-Farm Demonstration Project on Alley-Cover Cropping in Greensboro (Guildford County)

Based on case studies on climate resiliency on small farms and the needs assessment survey of small-scale farmers, an Alley Cover Crop Project is underway at the University Farm. The ANR staff taught farmers how better management practices could protect soil-water-farm resources on a small farm. The project is ongoing and is accessible to small-scale farmers and landowners as part of a demonstration plot designed to explain the benefits of using cover crops on small farms along with agroforestry (i.e., alley crops).

In 2022, one Franklin County farmer received information from this project and was following his family farm's alley cover cropping system. He stated:â" *his University Farm demonstration project led by you (ANR specialist) is a great way to showcase and influence people to practice in our farm, adopt regenerative practices and better ways to improve natural resources in our farm*."

Technical Assistance and Training

The ANR specialist provided an on-farm demonstration, educational training, workshop, and technical assistance on agriculture & natural resource management, climate change, and soil health.

Train-the-Trainer Workshop and Training (statewide)

Train-the-trainer workshops on soil health and regenerative and climate-smart agricultural resource management were presented to 28 stakeholders from N.C. A&T Cooperative Extension specialists/associates/agents, N.C. A&T faculty, USDA-NRCS, and FSA field staff, the NC Department of Agriculture and Consumer Services Forest Service, county forest rangers, and other community collaborators. Upon receiving this training, participants were able to provide necessary training to small-scale and limited-resource farmers and landowners and make them knowledgeable on how to follow regenerative climate-smart practices while protecting farm resources.

Small Farm Educational Forum Week: Soil Health and Natural Resource Workshop (Guildford County, March 2022)

The ANR specialist and his team provided hands-on train-the-trainer training on soil health and natural resources to 14 Extension county agents at the most prominent educational event for small-scale farmers, the Small Farms Week Educational Forum at N.C. A&T in Greensboro. One Extension agent from Franklin County mentioned:â" *I am very pleased to receive such a basic, handy training program on soil health that I feel confident and powerful now to go and talk about it to my farmers regularly*.

Hands-on Field Days at Farmers' Field (Franklin County)

Upon providing the train-the-trainer workshops, we hosted a hands-on field day in Franklin County to assist 20 farmers and landowners in finding solutions to their needs related to soil health and farm resource management practices in a changing climate. Audiences learned how to practice regenerative farming practices such as cover crops, conservation tillage, or organic amendments as best management practices to enhance soil, water, and environmental health.

***Farm Demonstration Workshop on Soil Health at Farmers' Field* (August 2022)**

The ANR specialist organized two on-farm demonstration workshops on soil health, climate change, and natural resources management for agroforestry/silvopasture systems. These were hands-on and farmer-oriented workshops where other attendee farmers saw and learned the techniques and adopted them on their farms. A total of 12 farmers participated from Franklin and nearby counties. One farmer commented during the event: "*This is one of very first field-based soil health and natural resource training organized by NCA&T Cooperative Extension by a natural resource specialist at a small-scale farm and I want more of this.*" At least two farmers are trying to implement a silvopasture/agroforestry system on their family farm

On-Farm Demonstrations (University Farm; Guildford County)

Following hands-on training, we organized 12 on-farm demonstrations for small-scale farmers with the help of our community partners to more realistically meet our client's needs at N.C. A&T's University Farm (a 430 acre living laboratory for farm demonstrations).

***Educational Tour on Alley-Cover Cropping* (silvopasture Project) at University Farm; Guildford County) (Oct 2022)**.

The ANR specialist *hosted an educational tour on an a*lley cover crop experimental plot at the University Farm as a part of the Forest Farming Education class. The county agents visited our plot at the farm with 10 farmers and learned how to manage agroforestry/forestry/cover crops for small-scale plots. Participants in this class/tour learned how growing cover crops in agroforestry set-ups on a small farm could be profitable for farms and how to manage their natural resources (soil, water, etc.). One attendee later mentioned to the Extension agent: "*This farm demonstration is very helpful to see how a small farm can be transferred into a model agroforestry farm if you have all the necessary training and information.*"

Soil Health Learning Community with Stakeholders (Statewide)

In 2022, the ANR specialist initiated a Soil Health Learning Community with stakeholders through individualized and group consultations, in which Extension specialists, n county agents, and farmers could all participate. It's a learning platform where we provide knowledge on soil testing and soil health as a part of climate-smart agricultural practices. We provided group or individualized consultations on soil testing and soil health, both in-person or online, to assist farmers with more detailed information on best management practices for their farms and land. Extension agents, farmers, and landowners (~statewide) are now more engaged in discussing their soil health and natural resources management strategies and implementing practices such as cover crops, no-tillage or minimum tillage, and diverse crop rotation. The local NRCS office mentioned: "*This type of soil health learning body was a much-needed informal team we need to educate the farmers and Extension agents about soil health and natural resources with science-based educational information.*"

Diversity Equity Inclusion and Accessibility Training on Natural Resource Protection

We are committed to promoting DEIA by connecting historically underserved, minority, BIPOC, and underrepresented groups with federal, regional, and local agencies through information gathering, distribution, and grantsmanship.

As a unique approach and as a member of the NC Cooperative Extension DEIA Core Committee, the ANR specialist introduced 28 farmers to educational training on DEIA issues as part of natural resource management training during the North Carolina Statewide Extension Conference.

Tabling Events @Farm Aid Festival on Climate and Soil (Wake County; Sept 2022)

The ANR specialist presented as a tabling event at the North Carolina Farm Aid Festival. We utilized resources provided through the RREA and made the public aware of climate change and natural resource management. In this state-level event, approximately 55 people visited our table and learned about good soil health and regenerative practices from our showcase.

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

Through our research-based technical assistance, training, workshops, on-farm demonstrations, field days, and learning platforms, farmers and growers (row or cash crops, vegetable crops, horticulture crops, specialty crops), ranchers, and landowners increase their knowledge of best management practices for soil, water, and natural resources, e.g., soil health. Our audiences get trained on soil testing and health, climate-smart, and regenerative practices such as cover crops, crop

rotation, conservation tillage (no-till, minimum till, etc.), and organic amendments (compost, manure, biochar, mulching, etc.). For example, in the soil health train-the-trainer program, 14 Extension at A&T county agents received natural resource kits (aka soil health test kits) for farm assessment. . As a result, more stakeholders in NC are getting engaged in climate-smart crop production. An increasing number of Extension agents are training self-sufficient farmers to provide training with necessary resources. Additionally, the on-farm demonstration project on Alley Cover Cropping is helping farmers plant cover crops on their small farms while growing forestry or agroforestry products for farm profitability.. Furthermore, the farm demonstration workshop on soil health at Farmers' Field motivated farmers to practice silvopasture systems in their farms to adopt best management practices. It also helped to improve sustainable plant production. N.C. A&T Extension has also reached out to more stakeholders and is gathering knowledge throughout the state about soil health measurement and practices through our Soil Health Learning Community. As a result, farmers are gaining an increased understanding of utilizing no-till or conservation tillage on their farms.

The ANR agent in Watauga County worked with three growers in 2022 to integrate crop rotation, cover crop management, and tissue testing to help these organic farms maximize the health and productivity of their soils, both in high tunnels and in outdoor field production. Drawing upon a network of agency partners and private sector suppliers, Extension helped these and other small farms source the fertility inputs they needed while stretching farm dollars as far as possible during this increase in expenses. Pre-season soil testing, fertilizer consultations at Against the Grain Farm, and in-season tissue testing resulted in a gain of about20**%** in marketable high-tunnel organic tomatoes. Optimal pre-plant fertility, combining composts, and bagged organic nutrients minimized the need for time-consuming foliar feeding, decreasing labor inputs to this successful tomato crop by about 5**%**. Thanks to routine tissue testing, a timely side-dressing of potassium sulfate virtually eliminated late-season fruiting problems that had challenged this farm in pastyears. Comprehensive soil testing and consultation with Springhouse Farm helped facilitate diversification into increased cut flower harvests while maintaining core production of vegetable crops. Soil management on this farm was further enhanced by Extension-recommended cereal rye and buckwheat cover crops at seasonally appropriate times and transitioning many of the fields to reduced-tillage or permanent bed production systems. At Rose Mountain Farm, soil testing and management recommendations enabled new terraces to come into meaningful production the first year following their grading and high tunnel installations. Farm acreage in production increased by 10**%** this year, while harvests and net profitability increased by 15**%**.

A small producer contacted the ANR agent in Stokes County with vegetable production issues. The family ordered a truckload of growing media for their expanding market garden. The US defines media as a substance through which roots grow and extract water and nutrients. The garden in which the media was added could not sustain plant life, and each vegetable plant died. Due to plant loss, the producer could not participate in the local Walnut Cover Farmers Market for the 2022 market season. The ANR agent in Stokes County was able to utilize Extensions' connections by reaching out to partner organizations to identify issues in the media. A media sample was submitted to the North Carolina Department of Agriculture (NCDA) and Consumer Services, Agronomic Services Division Soil Science lab. A detailed report was received from the NCDA agronomist describing the media issues. The agent contacted a regional NCDA agronomist for a more detailed explanation and guidance. Also, a regional horticulture specialist and a regional greenhouse specialistwere contacted to see if other issues had been reported with growing media in the state. The lab results indicated high salt build-up and varying pH levels in the medium. Based on the lab analysis and information provided by NC Cooperative Extension and NCDA Agronomic Services Division, the producer received a full refund ($3,000) from the media company. The agent continued working with the producer to develop a recovery plan. This plan included composting the media and consistent water pour-through to help leach the salts. Additionally, another media sample will be submitted for analysis in early 2023 to assess salt and pH levels. Cooperative Extension is helping get this family market garden back up and running for the 2023 growing season.

Granville wilt is a bacterial disease affecting the tobacco plant, discovered in 1881 in Granville County. Granville wilt thrives under moist and hot conditions. It works its way into the plant through surface wounds and then multiplies rapidly into the vascular system, producing a slimy mucous that plugs up the plant's vessels and causes the tobacco to wilt. The bacteria that cause the disease are carried throughout tobacco production on transplants, plow points, other farm equipment, and the feet of humans and animals. This year we had a lot of rain and high temperatures. These were excellent conditions for the disease to develop. There were several cases in Caswell County. When the small farms agent in Caswell County was made aware of the situation, he visited the farms and noticed many damaged tobacco fields. Specifically, wilting and yellowing of younger leaves was observed on tobacco plants. Plants' tissue samples were then taken for analysis at the plant disease and insects clinic in Raleigh. Granville wilt and hollow stalk were diagnosed on the submitted samples. The bacterium that causes hollow stalk invades the plant through a wound and causes the pith to turn brown and rot. There is no control at this stage for Granville

wilt since the causal organism can survive for years in the soil. The farmers were given best practices, including (a) cultivating plants early at shallow depth and (b) using resistant varieties and avoiding topping and sucker control measures during periods of high moisture. Since there are no chemical controls for this pathogen, the agent estimated the loss and provided a recommendation letter to farmers to use for crop insurance claims. Farmers in the county saved thousands of dollars through the crop insurance program using Extension's support.

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

Our ANRM and SHP are aimed to help the farming and broader community in the following ways:

Community Building: Through the Soil Health Learning Community with the multi-stakeholder group in the state and outside, we are providing the following information on soil health, and climate-smart and regenerative agricultural practices.

1. Identifying resources that meet the needs of the community.

2. Hosting, facilitating, and/or supporting community-building and networking events through our training.

3. Creating promotional materials and supply resources.

4. Hosting, facilitating, and supporting farm field days, meetings, and workshops.

Workforce Training and Development for Next Generation

We train next-generation beginning farmers and youth to develop an agriculture workforce with proper scientific knowledge on soil health and the importance of regenerative and climate-smart agriculture in a changing climate. In detail, we:

1. Create more awareness of opportunities to work in climate-smart and regenerative farm operations.

2. Develop a partnership plan with community groups to diversify farming practices and promote soil health practices.

3. Connect with more climate-smart agricultural resources and opportunities to create a pipeline for future generations of farmers.

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 are developing a series of soil health fact sheets and Extension publications focusing on basic soil health practices, regenerative agriculture practices, cover crops, conservation tillage, crop rotation, and organic amendments. We will make our soil health learning community platform more resourceful through these educational materials with appropriate videography. As a first step, we have developed two documents as part of our soil health learning community. These are 1) a guide to the proper way of collecting soil samples for soil health tests; and 2) a questionnaire document as a fact sheet.

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.

Cooperative Extension at N.C. A&T is dedicated to helping small and limited-resource farmers understand and manage their natural resources to improve production and reduce their environmental footprint. Projects aimed at protecting the soil, water, and environment on farmland included distributing comprehensive soil testing kits, an on-farm demonstration on

using cover crops and education about their value, technical assistance by Extension agents and other professionals, field days, educational tours, and a variety of special events. Extension agents also received training on soil health and natural resources. These programs offered farmers important knowledge about best management practices for soil, water, and natural resource management.

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 the development of nano-particle biomaterials with meaningful impacts related to Protecting Environmental and Natural Resources. The research focused on process development for biochar made from various bio-based materials and the use of biochar in advanced biomaterials to address needs for biofuels, energy storage, radiation protection and contaminant removal from waste water.

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.

Goal of the project is to perform research on thermochemical conversion (both pyrolysis and HTC) as a technology 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. Developed magnetic biochar-based carbon materials for removing phosphate from wastewater. Various biochars were produced from hard wood, hemp, miscanthus and soybean meal via thermochemical converison technology. Then the obtained biochars were characterized. The biochars were also chemically activated using KOH and modified with ferric oxide for phosphate removal investigation. Results show both temperature and feedstock type affect solid biochar yield. The modified biochar from miscanthus showed highest removal efficiency for phosphate (96%).

2. Developed Fluorine-Intercalated Biochar Material for Radiation Shielding and Carbon Capture. A fluorine-intercalated biochar-based carbon material was developed by activating and applying pyrrolic and fluoric functional groups to the surface. This functional material allow biochar to be use in capturing and removing CO2 from a mixture of gasses.

3. Developed novel N-doped carbon nanofibers for high performance capacitors. A aerogel carbon material with carbon nanofibers and wood biochar is fabricated for supercapacitor electrode use. Fluorine doping is also studied to further improve the electrochemical performance of N-doped carbon nanofibers.

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 option for soils and 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 bioenergy 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 have interests 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 states of 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 will 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 provided new business opportunities for various industries (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 3 graduate and 2 undergraduate students who will have more chances to be hired in the bio-based industry. The project also provided hands-on learning opportunities for other 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. Economic impact and sustainability of newly developed bio-based materials will be assessed during the next reporting period.

Publications:

1. Md Faruque Hasan,Shobha Mantripragada,Spero Gbewonyo,Shuangning Xiu,Abolghasem Shahbazi,Lifeng Zhang. (2022) Carbon nanofibrous electrode material from electrospinning of chlorella (microalgae) with polyacrylonitrile for practical high-performance supercapacitor. Int J Energy Res.2022, 1–16.

2. S., Xiu, Sutton, K. and Shahbazi, A. Development of Fluorine-Intercalated Biochar Material for Carbon Capture 1890 ARD Research Symposium 2022, Atlanta, GA. Apr.2-5, 2022 (Poster Presentation)

3. S., Xiu, Sennou, A. and Shahbazi, A. Development of biochars from biomass Hydrothermal Carbonization and pyrolysis for phosphate removal from wastewater. 1890 ARD Research Symposium 2022, Atlanta, GA. Apr.2-5, 2022 (Poster Presentation)

4. M. F. Hasan, S.Xiu, A. Shahbazi and L. Zhang. Carbon Nanofibrous Aerogel Material with Wood Biochar for Electrical Energy Storage.1890 ARD Research Symposium 2022, Atlanta, GA. Apr.2-5, 2022 (Oral Presentation) 5. Khiry Sutton, Shuangning Xiu, Shahbazi,A. (2021) Development of fluorine-intercalated biochar material for radiation shielding. Journal of Analytical and Applied Pyrolysis. 155,105038

Understanding interactions among species, climate change, landscapes, and nutrients in freshwater ecosystems

Project Director
Brad Taylor
Organization
North Carolina State University
Accession Number
1024021

Annual Result: Understanding interactions among species, climate change, landscapes, and nutrients in freshwater ecosystems

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

My research explores a variety of questions that advance our understanding of how interactions among nutrients, algae, detritus, invertebrates, and vertebrates, such as fish, respond to environmental changes (including agricultural landuse, restoration of agriculturally dominated lands, and climate-change effects on species distributions and emerging invasive species) in order protect protect the environment and natural resources and to predict such effects in natural and managed ecosystems. I use a diversity of approaches in my research, including species diversity surveys, observations and experiments in the field and lab, simulation modeling, and I collaborate not only with other ecologists both also with geneticists and geomorphologist to study and develop sustainable solutions to these environmental challenges. My current projects include: 1) Exploring linkages between food elemental composition and infectious diseases and taste modalities that have implications for agricultural systems and human nutrition. 2) Testing the supplementation insect egg-laying habitats (rocks and woody debrus) to enhance the recruitment of adult stream insects and accelerate the biological recovery of waters impacted largely by poor agriculturally practices in western North Carolina. 3) Reconciling how algae blooms can form in relatively low-nutrient streams unimpacted by agricultural runoff. 4) Investigate the impacts of climate-induced changes in key hydrologic events during the spring-fall progression (a seasonal hot moment) of nutrient uptake in headwater streams (network hotspots), in order to understand and predict how these ecosystems are changing in their ability to uptake, transform, and retain excess nutrients from agriculture and other human sources. 5) Using high elevation ponds as model systems for understanding how climate-induced shifts in species distributions affect ecosystem processes, such as carbon fluxes and storage and mineralization of nutrients limiting to biomass production of animals such as fish and birds.

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 research has advanced the field of ecology in several ways. First, our synthesis of species-specific nutrient excretion (Balik *et al.* 2018 *Ecosystems*) and detritus consumption rates (Balik *et al.* 2022 *Oecologia*) has revealed that even closely related (congeneric or confamilial) species can show pronounced differences in functional traits that have meaningful impacts on species' roles in ecosystem processes. Moreover, models incorporating species traits like body mass, diet composition, and the duration and phenology of life histories can generate accurate predictions of assemblage-wide ecosystem function rates in natural systems. This work emphasizes that functional trait models are a promising tool for anticipating the ecosystem consequences of changes in species assemblages.

Second, our most recent published work (Balik *et al. in press Communications Biology*) is among the first to combine long-term multigenerational species abundance data in a system subject to range shifts with functional trait-based models of ecosystem processes. These models predict that the contribution of range-shifting species to ecosystem process rates has been modest, and only occurs when a species with novel functional and life history traits supplants resident species' biomass. We suggest that range-expanding species with life histories or developmental strategies that differ from residents may quickly attain larger populations in new systems, whereas competitive interactions are more likely to limit range-expanding species with life history strategies similar to residents. Thus, in addition to functional traits which can predict species' contributions to ecosystem processes, consideration of other life history traits can provide useful insight as to why some range expansions cause shifts in species abundance or composition and others do not**.** These outcomes are of broad interest to ecologists trying to anticipate and mitigate the influence of range shifts in ecosystem processes and services.

Third, our research on food, taste and stoichiometry has led to the development of a new ecological concept (Taylor et al. *in press Bioscience*) describing interactions between species based on food and providing food. The concept, which we have called nature's chefs, outlines how species have evolved ways to produce food or drink items for other species, or deceive other species into thinking they are providing nutrition, to the ends of ensuring the success of the chef's offspring and genes. We identified three ways organisms attract other animals: with a) food (e.g., fleshy fruits, nuptial gifts), b) drink (e.g., nectar) and c) lures (e.g., angler fish bioluminescence). In each case, the "chef" species attracts other species in order to benefit its own fitness, like how plants produce fleshy fruits (foods) in order to attract animals to eat those fruits, ingest their seeds, and deposit those seeds at a distance. We also propose several future directions that deserve further study to evaluate how nature's chefs can serve as a holistic concept to synthesize species interactions ranging from mutualism to predation. This seemingly esoteric research project has societal relevance. Many non-human species perform roles analogous to chefs, and we introduce the concept of "nature's chefs" using examples from plant, animal, and fungal kingdoms in aquatic and terrestrial ecosystems. The concept of nature's chefs unifies the ways disparate species prepare, use, and perceive foods. Considering chefs holistically (i.e., both nature's and human's) can lead to discoveries in natural sciences that may apply to food and culinary sciences, culinary arts and food industries, and also for how humans think about food.

Fourth, our research on stream restoration (Jordt and Taylor *revised for Ecological Applications*) has provided proof-of-concept for the application of adding egg-laying habitat to restored streams or incorporating this into restoration designs as a way to accelerate the biological recovery of macroinvertebrate communities in streams, which is the metric used to evaluate

restoration effectiveness. This is important locally where millions of dollars are invested in stream restoration as well as nationally and globally where billions of dollars are invested in restoration.

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

We engaged our target audiences through publishing our work in top-tier peer reviewed journals in the field and presented at local and national meetings. We have engaged the public with our science through outreach events (adults and K-12 programs) and press releases here in North Carolina, Colorado, and in other US States and internationallly via collaborators.

Taylor, B.W., Allf, B, Hopkins, S.R., Irwin, R.E., Jewell, M., Nevo, O., Nichols, L.M., Rodríguez Valerón, N., Evans, J.D., Sörensen, P.M., Dunn, R.R. in press. Nature's Chefs: Uniting the Hidden Diversity of Food Making and Preparing Species Across the Tree of Life. *Bioscience*.

Jordt, S., and Taylor, B.W. Facilitating the recovery of insect communities in restored streams by increasing oviposition habitat. *Revised for Ecological Applications*.

Balik, J.A., Greig, H.S., Taylor, B.W., Wissinger, S.A. in press. Consequences of climate-induced range expansions on multiple ecosystem functions. *Communications Biology.*

Balik, J.A., Leitz, C., Washko, S.E., Cleveland, B., Krejsa, D.M., Perchik, M.E., Stogsdill, A., Vlah, M., Demi, L.M., Greig, H.S., Shepard, I.D., Taylor, B.W., Wilmot, O.J., Wissinger, S.A. 2022. Species-specific traits predict whole-assemblage detritus processing by pond invertebrates. *Oecologia*. https://doi.org/10.1007/s00442-022-05239-z

Balik, J.A., Jameson, E.E., Wissinger, S.A., Whiteman, H.H., & Taylor, B.W. 2021. Animal-Driven Nutrient Supply Declines Relative to Ecosystem Nutrient Demand Along a Pond Hydroperiod Gradient. *Ecosystems* 1-19. https://doi.org/10.1007/s10021-021-00679-9

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

Species range shifts are among the most widespread ecological responses to climate change, and are therefore impacting society in a variety of ways. For example, the expanding range of ticks is spreading lyme disease northward along the east coast of North America, shifts in distribution of near-shore fish species is changing coastal ecosystems and their fisheries, and the expansion in the range of forest pests is having cultural and economic impacts in many communities. Our research has developed and tested tools that could help improve the ability of managers to anticipate how ecosystem processes that underlie natural resources such as potable water respond to altered species assemblages as organisms respond to changing climates.

Our work on increasing the effectiveness of stream restoration will benefit stream restoration practioners who are eager to increase the value-addedness of their work to competitve for State and Federal contracts.

Food is a topic that garners broad interest and the concept of nature's chefs will benefit the broader public by increasing their knowledge of what constitutes food, how it is made, what organisms make food, and how humans might be able to learn fro nature to make more sustainable foods. For example, how might we learn from nature to produce plant-based foods that have meaty flavors? Are there plants in nature that mimic meat to attract carnivores? If so, it would be straightforward to study and learn from such plants to develop new food and culinary approaches to consume plant-based meaty foods. Avocados have been noted to attract felids, particularly when planted as orchards and even cats as big as jaguars have been seen consuming the fruits. Durian fruits have been argued to be dispersed by tigers.

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.

DELIVERED INSIGHTS AND TOOLS FOR SUPPORTING FRESHWATER ECOSYSTEM HEALTH: Evolving and increasingly complex environmental challenges create an urgent need to protect environmental resources by understanding how various plants, animals, and other organisms respond to large-scale changes, including agricultural land use, restoration of agriculturally dominated lands, and climate change. NC State researchers use species diversity surveys, field and lab experiments, and collaborations with ecologists, geneticists, and other specialists to study and develop sustainable solutions to environmental challenges. To date, they have advanced the field of ecology by identifying models that can anticipate the ecosystem consequences of changes in species' communities and developing models to predict territorial spread and competition among species. They have also developed the "nature's chefs" concept, which outlines how species have evolved ways to produce food for other species, or deceive other species into thinking they are providing food, in order to ensure the success of the "chef's" offspring and genes. In addition to enhancing the ability to predict and respond to the effects of environmental change at the species and ecosystem levels, this research lays groundwork for discoveries that may advance culinary and nutritional science and change how humans think about food. For example, they could lead to the production of fruits that taste like meat. Researchers have also provided proof-of-concept for a new method to accelerate the biological recovery of stream-dwelling insects, assess restoration success, and import restoration techniques to freshwater fisheries. These insights were shared through publications in peer-reviewed journals, local and national presentations, public outreach events, and press releases.

delete

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

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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.

x

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

x

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

x

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.

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Soilless Substrate Engineering, Characterization, and Management in Container Production Systems

Project Director

Brian Jackson

Organization

North Carolina State University

Accession Number

1020642

Annual Result: Soilless Substrate Engineering, Characterization, and Management in Container Production Systems

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

This project involves the R&D of organic agricultural and industrial materials/residuals to create components to be used in the formulation of soilless growing mixes (potting soils). These horticultural substrates are used in the production of billions of plants across nearly all agricultural plant commodities. Growing all plants in soilless systems (out of the ground) requires some material (substrate) to put in the pots for the plants to grow in. Traditionally (for more than 60 years) the main material used for this purpose has been peat moss. Due to severe (and growing environmental concerns of extracting peat moss from natural wetland bogs and the resulting carbon release, the efforts, energies, interest, and need for peat alternative substrates has never been higher. The scope and goals of this project are to develop novel substrates and substrate components from wood and bark-based materials (forest products). We also identify, test, and analyze other agricultural and industrial materials and by-products as well for this application.

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.

Activities this year were excelerated due to the increased interest and impact of reseach in applied horticulture production areas. The incredibe increase is consumer purchasing and consumption of horticultural crops (plants and soils) also created tremendous demand for research results and product development. This interest led to my major activities during this time period being heavily focused on research projects and horticulture industry partnerships more than at any other time period in the past. Innovative research and development of forest-based biomaterials into viable substrate components and the use of these materials at higher incorporation rates, was very successful. These activities to pursue research projects and collaborative initiatives surrounding the reduction of peat moss usage in horticulture by creating alternative substrate materials was very productive with many publications, invitations to speak, and visits to growers and growing media (substrate) producers. There were no major setbacks for problems with the project during this timeframe. Even with the issues still surrounding the pandemic, progress with made with training/educating graduate students, conducting new research projects, initiating new projects on soilless substrates, and creating new collaborative opportunities with other scientists and industry professionals. During this time period I was able to travel once again to visit greenhouse and nursery plant growers and share updated research and also conduct training and workshops. A lot of effort was also made to continue using industry trade (popular press) magazines as delivery platforms to reach more of the public (and industry stakeholders) in a more timely fashion than formal research papers/reports or annual meetings. There is much work and many ongoing (existing) projects that will be continued into the next year (reporting cycle).

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

There is a very large (and growing) interest across the US and North America (also globe) to reduce the extraction and use of peat moss. This therefore requires new material development and innovations in the substrate product line. The national and global interest to identify alternatives to peat is exactly what this project (and my program) has been working towards for over a decade. This interest coupled with great industry support has yielded the opportunity to further our efforts and outcomes on developing wood-based materials here in NC and across the US. Companies are now offering soil products that have a larger percent of wood-based components in them ...meaning less peat. My target audience for my research program and initiatives are greenhouse plant producers, outdoor nurvery crop growers, greenhouse vegetable and fruit growers, Christmas tree growers, and many other Specialty Crop producers. My target audience also includes all soilless substrate (growing media) producers in the state, region, and nation including producers/suppliers of peat moss, pine bark, wood fiber, composts, rice hulls, hemp fiber, and numerous other raw materials.

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

The development of alternative, local, and more sustainable soil products to grow plants has spread well beyond larger professional growers and now has the interest and attention of the broader public. The broader public, those who are not professional plant growers (greenhouses or nurseries) directly benefited from results of this research project by being able to access and purchase more peat alterative soil products at garden centers and other distribution centers. The result of these projects that have continued to develop (and tweak) alternative substrates for professional plant growers has (as it was meant to) also affected the soil producers who create retail/consumer garden products. Consumer soil products contain less peat moss now, holistically, than at any time in the past several decades. Consumers are aware of the issues with peat moss and have been demanding more sustainable and local products. The pandemic has elevated this concern and desire.

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.

REDUCED ENVIRONMENTAL IMPACT OF PEAT MOSS HARVESTING BY DEVELOPING ALTERNATIVE SOILLESS GROWING MATERIALS: Soilless systems are used to produce billions of plants across nearly all agricultural plant commodities. For over 60 years, the main substrate (or growing material) used for this purpose has been peat moss. Because extracting peat moss from natural wetland bogs releases carbon and contributes to climate change, the need for alternative substrates has never been higher. To address this need, NC State researchers have developed forest-based biomaterials that can be used as agricultural substrates to replace peat moss. These research efforts have resulted in many collaborative initiatives, publications, presentations, and visits to growers and substrate producers. The results of this research have also been shared with industry and with the general public through trainings, workshops, and trade magazines. Thanks to these efforts, a broad range of specialty crop producers, soilless substrate producers, and the broader public have benefitted from increased access to peat-alternative soil products, allowing them to efficiently produce crops while minimizing negative environmental effects.

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

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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.

x

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

x

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

x

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.

x

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

Final Result: Keeping afloat in the data deluge: coupling observational data, analytics, and integrated models to propel data-driven biological resources management

Final Result

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

Natural and agricultural systems are increasingly monitored through wide-ranging sensors, including those on satellites and installed in the field. Our ability to collect measurements from natural and agricultural systems has grown at a rapid pace, but the development of tools and analyses that produce management-relevant information from these ever-growing datasets has

not occurred at the same rate.

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 demonstrate how environmental and agricultural datasets could be used to drive models or develop new modeling tools, several case studies were conducted through which diverse environmental and agricultural datasets were analyzed using data-intensive methods including machine learning, statistical modeling, and simulation modeling. The case studies required new collaborations with scientists from ranging disciplines, as well as stakeholders like regulators and producers. Examples of agricultural and environmental systems analyzed include shellfish mariculture, cotton and sweetpotato production, and hog farming. Major activities included forging new collaborations, analyzing datasets and producing models, disseminating findings through publications and presentations, and training student and postdoctoral researchers.

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

The target audience for this project included practitioners and applied researchers working in natural and agricultural resources management, as well as students and postdoctoral researchers. Practitioners and applied researchers benefited by having access to new models and datasets, as well as publications outlining methods and frameworks for producing predictive models and decision-support tools from environmental and agricultural data. For example, using long-term and historical satellite image archives, we determined when concentrated swine feeding operations were constructed across North Carolina, which had previously not been known, and published the data publicly for other researchers and practitioners to access and use. As another example, we created a forecasting system for shellfish growers to anticipate when temporary harvest closures might occur, and created a web application through which the forecasts can be accessed and visualized. Fact sheets were also produced to help make data analysis tools more accessible. One example of a fact sheet created through this project is “Getting Data from the National Agricultural Statistics Service (NASS) Using R”, which was published through NC Cooperative Extension. Lastly, graduate students and postdocs were trained and provided with opportunities to advance their professional development by attending conferences, working with multidisciplinary teams, and creating research and outreach products.

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

By analyzing environmental and agricultural datasets and producing models, the project advanced understanding of how environmental and agricultural systems behave, while also creating tools that help natural and agricultural resource managers more effectively allocate resources and make data-driven decisions. The project also created information, such as datasets, for other applied researchers to use towards producing new findings in their respective disciplines, thus helping to advance scientific understanding. Lastly, by training students and postdoctoral researchers, the project supports workforce development by supporting the creation of a new generation of researchers who understand how to apply data science methods in support of agricultural and natural resources management.

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.

DELIVERED INSIGHTS TO ENHANCE DATA-DRIVEN MANAGEMENT OF NATURAL AND AGRICULTURAL RESOURCES: Natural and agricultural systems are increasingly monitored through wide-ranging sensors, including those on satellites and installed in the field. But our ability to collect measurements from natural and agricultural systems has progressed more rapidly than the development of tools and analyses that enable stakeholders to make sense of these ever-growing datasets, creating an urgent need for new approaches to interpreting and managing this data. To meet this need, NC State researchers have collaborated with scientists, regulators, producers, and other stakeholders to analyze diverse environmental and agricultural datasets using methods such as machine learning and statistical modeling. Advantages gained from this research include the creation of a harvest closure forecasting system and accompanying web application for shellfish producers and the creation of various fact sheets to make data analysis tools more accessible. This research was shared through publications, presentations, and specialized training, benefitting researchers and other stakeholders in natural and agricultural resource management. By empowering researchers and growers to better understand and manage natural resources, this research supports the development of a more robust, data-driven approach to preserving the environment and building a resilient food supply.

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

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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.

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

x

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

x

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.

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Type	Projects / Programs
Projects / Programs without a Critical Issue	**1**

Small Farmers' Readiness to Adopt and Consumers' Willingness to Pay for Value-Added

Project Director

Obed Quaicoe

Organization

North Carolina Agricultural and Technical State University

Accession Number

1019916

Factors Influencing Small Farmers' Readiness to Adopt and Consumers' Willingness to Pay for Value-added Agriculture in North Carolina

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

This project addresses the North Carolina farm industry, which is facing decreasing profitability. As such the future sustainability of many small farm operations is linked to the ability of farmers to generate supplemental income from existing farm resources. This project examines the factors that influence value-added agriculture on both the consumer and producer side in order to enhance farm profitability among small farmers 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.

During this reporting period researchers developed and conducted a small farmer value-added workshop to provide farmers with value-added agricultural information. The workshop featured speakers from the North Carolina Department of Agriculture, a successful value-added farmer, and an agricultural financial consultant. Researchers provided preliminary findings of the project gained through the analysis of focus group data. Additionally, the research team finished the development of the consumer value-added questionnaire, which was approved by IRB and disseminated via Qualtrics. Researchers are cleaning up the data for analysis. Although the consumer focus group provided preliminary findings to achieve objective 1, the results from the analysis of the consumer survey data will provide detailed findings about consumers. To streamline the small farmer questionnaire, the research team submitted a revision to the IRB, which was approved. The team and cooperative extension agents disseminated the revised questionnaire at the NC Minority Farmers & Landowners

Conference and at the North Carolina A&T State University Small Farmers Field Day. A data entry template and variable codebook have been generated and researchers are currently in the process of inputting the data for analysis. Although the farmer focus group provided preliminary findings to achieve objective 2, results from the analysis of the farmer survey data will provide detailed findings about farmers. Objective 3 will be completed once both consumer and small farmer datasets are analyzed.

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

The small farmer value-added workshop provided useful information to the project's target audience of small and socially disadvantaged farmers in North Carolina. The workshop provided useful information concerning value-added activities, such as agritourism and agricultural financial information, as well. The North Carolina Department of Agriculture's Agritourism Marketing Specialist provided statistics supporting agritourism as a viable value-added operation. The agricultural financial specialist provided farmers with accounting and tax information to assist with agricultural operations. Additionally, the research team was able to provide useful value-added data garnered from the project's focus groups and questionnaires. Findings such as the amount consumers are willing to pay for value-added products, products that interest consumers, the manner in which to offer these products, and other pertinent information that could have an impact on their acceptance of value-added agriculture or operations were shared. Farmers were also able to receive first-hand information from a successful North Carolina value-added farmer. The farmer was able to discuss some of the issues faced by running a successful value-added agricultural farm, as well as, provide insight into the profitability of value-added agriculture.

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

Being that the sustainability of agriculture is essential to the well-being of society, the project's goal of generating supplemental income to assist with the viability of farmers benefits the public, as a whole. The project team developed an IRB-approved consumer value-added questionnaire, which allowed the public to voice their preferences concerning value-added agriculture. Consumers were asked questions related to their value-added wants, prices willing to pay for value-added items, farmers' market usage, community supported agriculture participation, among other questions. Having the ability to communicate their wants to farmers benefits both parties. The aforementioned survey data is currently being analyzed. After which, farmers will be able to apply the information to their agricultural operations to determine if they would like to participate in value-added agriculture.

Additionally, the research team conducted a value-added workshop that provided farmers with useful value-added information concerning agritourism, agricultural finances and first hand value-added farmer information. The workshop and questionnaire contribute to the project team's overall goal which contributes to food security, food safety and farm profitability.

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.

Although Covid-19 served as an initial barrier in the approach of the project, the research team was able to pivot during the previous research years and utilize Zoom, Qualtrics, email, electronic newsletters and, other electronic forms of communication in order to facilitate workshops, disseminate questionnaires and garner interest in the project. The project has offered opportunities for training and professional development by providing workshops that disseminated value-added information and project findings to communities of interest. The project findings have also been disseminated via conference presentations and journal publications. Additionally, questionnaires and focus group facilitation have provided consumers with opportunities to express their interest in value-added, thus providing farmers with essential information that can be applied to their value-added agricultural operations.

The next steps include the research team continuing to disseminate workshop participation flyers and the small farmer questionnaire. The final value-added workshop will be facilitated and the consumer and small farmer value-added questionnaires will be analyzed in order to satisfy objective 4 of the project.

Conference Presentations/Publications:

Quaicoe, O., Vorsah, R., Jefferson-Moore, K., Bynum, J., & Owens, J. (2022). What They Know and Why They Do It: Preliminary Findings of Farmer Focus Group Discussion on Value-Added Agriculture in North Carolina. Journal of Food Distribution Research Volume 53, Issue 1, pp. 19–22.

Quaicoe, O., Vorsah, R., Jefferson-Moore, K., Bynum, J., & Owens, J. (2022). What They Know and Why They Do It: Preliminary Findings of Farmer Focus Group Discussion on Value-Added Agriculture in North Carolina.Food Distribution Research Society 2021 Virtual Annual Meeting, Monday October 18, 2021(Oral Presentation)

Brooks, S., Jefferson-Moore, K., Quaicoe, O., Bynum, J., and Owens, J. . Developing a consumer profile for value-added products in North Carolina. Annual Meetings of the Food Distribution Research Society, October 22 - 25, 2022, Pensacola, FL. (Accepted for Paper Presentation)

Brooks, S., Jefferson-Moore, K., Quaicoe, O., Bynum, J., and Owens, J. (2022). Developing a consumer profile for value-added products in North Carolina. Annual Meetings of the Agricultural and Applied Economics Association, July 29 - August 3, 2022, Anaheim, CA. (Accepted for Poster Presentation)

Vorsah, R. (2022). *Factors Influencing Adoption of Value-Added Agricultural Practices among Small Farmers in North Carolina: Preliminary Findings of Farmer Focus Group Discussion*. [Masters Thesis, North Carolina Agricultural and Technical State University]. ProQuest Dissertations Publishing, 2022. 29325735.

Straughter, M. (2021). *A Qualitative Analysis of Consumer Preferences for Local Value-Added Products*. [Masters Thesis, North Carolina Agricultural and Technical State University]. ProQuest Dissertations Publishing, 2021. 28416465.