FY 2020 Annual Report of Accomplishments and Results

Tennessee
University of Tennessee (UT) Extension System (1862)
Tennessee State University (TSU) Extension System (1890)
University of Tennessee (UT) AgResearch – Tennessee Agricultural Experiment Station (1862)
Tennessee State University (TSU) Institute for Food, Agriculture and Environmental Research (1890)

I. Report Overview

The NIFA reviewer will refer to the executive summary submitted in your FY 2020 Plan of Work located in the Institutional Profile. Use this space to provide updates if needed.

1. Executive Summary (Optional)

2020 Updates

The COVID-19 pandemic has significantly impacted the operations of the land-grant system in Tennessee. Both UT and TSU have experienced significant disruptions in the execution of our planned programs in research and Extension. Even though our Extension professionals have done an admirable job of utilizing alternative means to fulfill needs for outreach, and our research scientists have gone through extraordinary measures to keep research projects (especially field experiments) alive and on track, full capacity will not be achieved until the country has the virus contained.

UT and TSU Extension extended the knowledge and expertise of the state's two land grant institutions to the 6.7 million people of Tennessee through agents and specialists in all 95 Tennessee counties. Our work is to provided education that produced solutions to societal, economic and environmental issues. Engagement of the state's citizens occurred where they live, work, and play through hundreds of programs which were planned, conducted, and evaluated by UT and TSU Extension. In 2020, Extension continued its leadership in economic development and outreach.

Extension Excellence in Economic Development: Extension's educational programs in 4-H youth development, agriculture and natural resources, family and consumer sciences, and community economic development produce substantial returns for Tennessee. Calculated by using research,

questionnaires, observations, and sales records, UT Extension's estimated economic impact was more than $548 million for 2020. It was estimated that for every $1 in public funds invested in Extension, $7.70 was returned to the people of Tennessee in increased revenues, increased savings, and one-time capital purchases. The recurring economic impacts were estimated at over $309.9 million. These recurring economic values include increased revenues, increased savings, and one-time capital purchases associated with Extension programs in crop variety trials/pest control, forage systems, pesticide safety education, integrated pest management, turfgrass weed management, apiculture, and optimizing livestock production. Using a UT System standard formula, an estimated 6,198 jobs were created or maintained because of the recurring economic impacts produced by Tennessee Extension. The one-time, non-recurring economic values were estimated at over $238.2 million from Extension programs in nutrition education, health literacy, financial management, volunteerism, and community service.

Extension's Excellence in Outreach: UT and TSU Extension professionals and the volunteers they recruited, trained, and managed made more than 3.48 million direct contacts through group meetings, onsite visits (farm, home, and workplace), phone calls, direct mail, and client visits to local Extension offices in 2020. In addition, indirect educational methods included mass media, exhibits, and Internet resources. The youth UT and TSU Extension had enrolled as of August 2020 in the Tennessee 4-H Program was 155,563. These youth numbers include those in clubs as well as participating non-club activities. Data for the Extension portion of this report utilized the Extension reporting system, System for University Planning, Evaluation and Reporting (SUPER). For the past 14 years, (2006-2020), this reporting system has been demonstrated to the administrators of 25 state Extension organizations who regarded it as a national model for Extension accountability.

UT AgResearch Strategic Action Plan: In 2020, UT AgResearch engaged a committee of faculty and staff across the UT Institute of Agriculture to develop a three-year strategic action plan to help meet the goals set forth in "A Decade of Excellence: Ten-Year Strategic Plan for UTIA, 2018-2028." The objectives of the AgResearch Strategic Action Plan (ASAP) are to balance a portfolio of integrated, inter-disciplinary programs, cultivate teams to approach complex problems, advance concepts with structured support, and to ensure research and development capacity with targeted investment. The ASAP calls for a focus on four main identified programmatic themes – One Health, digital agriculture, agricultural genomics and synthetic biology, and bioeconomy advancement; and the next critical area that may emerge in the foreseeable future. An ASAP Director was appointed to oversee the plan's implementation in concert with a newly established Faculty Innovation Council.

UT AgResearch and Education Centers Amid COVID-19 Pandemic: Despite the COVID-19 challenges, the number of field trials (~1050) conducted at the ten AgRECs in 2020 surpassed those in the previous two years (averaging ~900/yr). The normally in-person educational Field Days were mostly pivoted to virtual format. In particular, celebrating the 40th anniversary of Milan No-Till Farming Field Day, this virtual event

had far reaching impacts on the constituents in Tennessee, the United States, and the world in that the virtual presentations received over 14,000 views by more than 8,000 unique users from 44 states and 39 countries by the end of 2020.

TSU Research During COVID and Tornado Recovery: Despite the challenges imposed by COVID, TSU Research continues to its capabilities through the addition of new faculty in biotechnology, hemp production, and agricultural economics. We are also moving forward with the construction phase of a new stand-alone Food Science and Technology Building that will support our expanding expertise in food technology and food safety. The Agricultural Research and Extension Center associated with the TSU main campus was heavily damaged by a tornado in the spring of 2020. Although field operations have partially resumed, greenhouse, shadehouse, and indoor activities at the facility have are severely curtailed. The timeline for rebuilding dictates that research that requires these facilities will be significantly delayed for at least a year. Although our faculty have faced many challenges, this year we continue to be among the most productive 1890 universities in terms of competitive grants obtained and communication of results via refereed publications and presentations.

Merit and Scientific Peer Review Processes

The NIFA reviewer will refer to your 2020 Plan of Work. Use this space to provide updates as needed or activities that you would like to bring to NIFA's attention.

Process	Updates ONLY
1. The Merit Review Process	● Internal University Panel ● External University Panel ● Expert Peer Review The merit review and peer review processes established in the latest Plan of Work were implemented ten years ago. At that time, the external university panel review was completed with program planning and evaluation experts from Virginia Tech and the University of Maryland. This review panel found that the Tennessee Plan of Work was of exceptional quality. The panel's major suggestion was to continue a strong needs assessment and evaluation process focused on measuring substantial outcome indicators. The Plan of Work planned programs have only had minor changes since that time, therefore, an out of state review panel was not conducted in 2020.
2. The Scientific Peer Review Process	

Stakeholder Input

The NIFA reviewer will refer to your 2020 Plan of Work. Use this space to provide updates as needed or activities that you would like to bring to NIFA's attention.

Stakeholder Input Aspects	Updates ONLY
1. Actions taken to seek stakeholder input that encouraged their participation with a brief explanation	Refer to the Plan of Work. UTIA (AgResearch and Extension) and TSU leaders regularly interact with stakeholders, e.g., Tennessee Farm Bureau Federation (TFBF), Tennessee Department of Agriculture (TDA), and all the commodity organizations (corn, soybean, cotton, cattle, poultry, forestry, etc.) to ensure that our research and Extension programs are well aligned with the priorities identified by the stakeholders. Our interactions take the forms of external Regional Advisory Councils meetings, TFBF annual conferences, Agricultural Industry Partners meetings, stakeholder listening sessions, and UT Commission on Agriculture annual meetings.
2. Methods to identify individuals and groups and brief explanation.	UT and TSU Extension conducted the following methods: 94 advisory committee meetings, 60 key informant interviews, and multiple surveys in 2020.
3. Methods for collecting stakeholder input and brief explanation.	The System for University Planning, Evaluation and Reporting (SUPER) tracks Extension's needs assessment efforts across Tennessee.
4. A Statement of how the input will be considered and brief explanation of what you learned from your stakeholders.	Due to the COVID-19 pandemic and program participant feedback, UT and TSU Extension developed educational materials and programming that can be delivered in virtual environments.

II. Critical Issues Table of Contents

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V. Activities and Accomplishments

Please provide information for activities that represent the best work of your institution(s). In your outcome or impact statement, please include the following elements (in any order): 1) the issue and its significance (e.g. who cares and why); 2) a brief description of key activities undertaken to achieve the goals and objectives; 3) changes in knowledge, behavior, or condition resulting from the project or program's activities; 4) who benefited and how. Please weave supporting data into the narrative.

No.	Project or Program Title	Outcome/Impact Statement	Critical Issue Name or No.
1.	Tennessee Extension Beef Cattle Programs	Challenges facing the beef cattle industry in Tennessee range from the adoption of very basic management practices to complicated global market drivers that affect input costs. Nutritional, reproductive, genetic, and health management are the general areas that impact profitability most. UT and TSU Extension Agents and Specialists spent 29,613 hours conducting educational programs that reached 289,244 direct contacts. Best management practices in beef cattle production were taught at 1,745 group meetings, 4,729 on-site visits. These direct methods were reinforced by 10,433 digital communications and 653 mass outreach communications reaching an estimated 4.2 million indirect contacts. Volunteers invested 2,156 hours of their personal time to establish a total of 54,988 direct and indirect contacts.	Supporting Food, Fiber, and Energy Systems

		Notable outcomes of the program include the following: • 2,033 beef producers sold 58,061 calves that were managed for improved marketing methods, according to practices promoted by UT and TSU Extension, to increase returns by $4,493,953. • 1,792 beef producers utilized bulls (through natural service or artificial insemination) with greater genetic potential producing 44,860 head of calves to increase returns by $2,245,500.00. • 1,093 beef producers utilized 1,833 bulls (through natural service or artificial insemination) with greater genetic potential to produce 39,137 head of calves to increase returns by $2,131,850. • 1,040 beef producers implemented reproductive management by conducting pregnancy diagnosis on cows/heifers producing 30,290 head of calf increasing returns by $12,116,400. • 1,001 beef producers implemented reproductive management by conducting breeding soundness exams on 1,807 bulls ($9,735,000 increased returns) and pregnancy diagnosis on 15,627 cows/heifers ($6,250,800 increased returns). • TSU Extension worked with 994 beef producers who reported savings or increased returns of a total of $564,000. UT and TSU Extension programming for beef cattle production and management continued to enhance the lives and livelihood of Tennessee beef cattle producers. The total economic impact of UT Extension's beef cattle programming was estimated at more than $36.9 million in savings and additional revenue.	
2.	Tennessee Variety Test Program for Corn Grain, Silage, and Soybeans	Tennessee producers need information concerning corn and soybean variety test performance specific to their region to provide guidance in the	Supporting Food, Fiber, and Energy Systems

		selection of varieties/hybrids that will optimize the profitability of their production systems. The variety test program provides important information on which varieties perform best in Tennessee. In 2020, replicated variety tests were conducted on corn grain (87 hybrids; 16 brands), corn silage (8 hybrids; 3 brands), and soybeans (139 varieties; 19 brands) at six of UT's Research & Education Centers and AgriCenter International which represent the different physiographic regions of Tennessee. Data were collected on yield, quality, and agronomic traits. Results from these crop trials were compiled, along with results from the County Standard Tests (CST) and soybean disease variety trials and published in three peer-reviewed Extension publications. These were distributed electronically as both pdf and mobile-friendly, searchable tables on search.utcrops.com as well as through hard copies distributed to farmers, extension agents, seed industry reps, consultants and other interested clientele. In 2020, the variety test program provided an estimated $136.7 million in additional revenue to Tennessee producers. This number includes $34.7 million from corn and $102 million from soybean. These numbers were calculated by determining the monetary value of growing top performing varieties compared with varieties that exhibit average yield performance. Yield advantage was calculated by subtracting the test average from the average yield of top performing varieties, defined as varieties that did not differ statistically from the highest yielding variety within each test. In 2020, top performing varieties exhibited a yield advantage of +9 bu/a for	

		corn and +4 bu/a for soybeans. This number was multiplied by USDA reported price per bushel (corn - $4.24 and soy - $11.61) and Tennessee acreage harvested (corn – 900,000 and soy – 1.62 million) in 2020. This number was then multiplied by 0.88 based on results from a 2017 survey which indicated 88% of respondents use the variety test results to select top performing varieties. By helping producers distinguish between top-performing and average or poorly adapted varieties, the Tennessee variety test program provided an estimated $136.7 million ($34.7 million from corn, $102 million from soybean) in additional revenue to Tennessee producers in 2020. The variety test program has a significant economic impact to Tennessee and continues to be a program that is highly valued and supported by producers.	
3.	Forage Educational Programs for Livestock and Hay Producers – Weed Management	Livestock production in Tennessee depends primarily on forage crops for the feed supply. Grazing, hay, and haylage make up the overwhelming majority of livestock diets, and are the major cost in livestock production. Improving efficiency and decreasing costs are the primary focus of the forage educational program in Tennessee. UT Extension conducted forage educational programs reaching over 25,000 direct contacts during 2020. Stockpiling tall fescue and weed control, as well as adding clovers to grass pastures and utilizing warm-season forages were primary educational topics covered. These were taught through approximately 116 group meetings and almost 1300 on-site visits. These direct contacts were supported by almost 350,000 digital and mass media correspondence.	Supporting Food, Fiber, and Energy Systems

		Forage educational programs had over 25,000 contacts during 2020. These programs resulted in 27,773 acres being planted with clovers, 5876 acres planted to warm-season grasses for summer forage production, and 30,211 acres of tall fescue stockpiled to decrease winter feed costs. Over 79,000 acres of forage crops were treated to decrease weed pressure. Approximately 80,000 head of cattle were fed using improved feeding methods. The increase in forage profitability from these practices was significant. Based on data from research studies, the fertilizer savings from planting clovers was $694,000. The improved forage production from warm-season grasses is valued at a $117,000, while stockpiling tall fescue saved $1.5 million in feed costs. Weed control improved forage production by approximately $3.1 million. Improved hay feeding methods saved $2 million dollars in hay costs. The total impact of the forage educational program is valued at $7.5 million dollars.	
4.	Tennessee Row Crop Programming (Corn, Soybeans & Cotton)	Challenges facing the row crops industry include understanding and adopting changes in technology, integrated pest management, sustainable agronomic practices and profitability. Corn and soybeans were harvested on more than 870,000 and 1.65 million acres, respectively, in Tennessee in 2020. Harvested cotton acres for the 2020 season summed to more than 275,000 acres. The 2020 growing season was very challenging, weather wise, beginning with a wet, cold spring followed by a growing season that included moderate to hot temperatures and more plentiful rainfall across the state. Farmers reported good crop yields although most agreed the growing season was more challenging than the previous year.	Supporting Food, Fiber, and Energy Systems

		The final state corn yield averaged 165 bushels/acre, and soybeans yielded 49 bushels/acre (Jan 2020 NASS Quick stats). Commodity prices were low due to the large U.S. crop with producers receiving closer to $3.60 per bushel for their corn crop and $8.60 per bushel for their soybean crop on average. Projected cash receipts for 2020 corn grain in Tennessee are estimated at more than 516 million dollars, with more than 695 million dollars for soybean grain. Favorable environmental conditions and proper management in-season supported a final state average, as estimated by USDA, of over 1,100 lb lint per acre for cotton. Cash receipts for 2020 Tennessee cotton production are projected (at a 75-cent average price) to exceed 226 million dollars from lint alone. UT Extension agents and area Extension specialists conducted educational programs reaching over 41,000 direct and 2.1 million indirect contacts during 2020. Best production practices were taught at more than 407 group meetings and over 1492 on-farm visits. Direct contacts were supported by personal correspondence (30,819), group meetings (6,637) and on-site visits (3,598). Indirect contacts were supported by digital contacts (111,571) and mass outreach methods (1.99 million). Extension agents also provide vital information for the National Agriculture Statistics Service (NASS) Crop Weather Reporting for their respective regions. The data provided by agents are incorporated in the weekly weather and crop bulletins provided by the U.S. Department of Commerce and USDA.	

		Notable program outcomes include the following: • Soybean producers increased yield 853,633.8 total bushels by adopting two or more recommended production practices on 1,660,238 acres increasing total income by $7,341,250.68. • 897 of 1,009 (89%) soybean producers gained knowledge of UT recommended agronomic and pest management practices. • 700 of 923 (76%) soybean producers gained knowledge of UT recommended agronomic and pest management practices and 562 of 714 producers adopted two or more of those practices. • Corn producers increased yield 2,244,040.5 total bushels by adopting two or more recommended production practices on 1,123,104 acres increasing total income by $8,415,151.88. • 682 of 780 (87%) corn producers gained knowledge of UT recommended agronomic and pest management practices. • 371 of 496 (75%) corn producers adopted two or more of the recommended agronomic and pest management practices. • 353 cotton producers gained knowledge of UT recommended agronomic and pest management practices and 332 producers adopted those production practices. • 585 producers, farm workers and ag professionals received pesticide certification, recertification and pesticide safety training. • TSU agents worked with over 445 farms and families, who were able to improve practices and save money or increase revenue. Producers planted 1,088 acres with clover for an increased production valued at $32,640; weed control outreach produced an increased production value of $121,960, and education in tall fescue management reduced feeding cost by $126,920.	

		• 376 farmers, teachers, research and extension personnel were trained to use drone technology. • TSU Extension worked with 161 producers, extension agents, gardeners who were trained in organic certification process, organic vegetable production practices and vertical farming. UT and TSU Extension programming for row crop production with land and pest management continued to enhance the lives and livelihood of Tennessee row crop producers. The total economic impact of UT Extension's row crop programming was estimated at more than $16 million in savings and additional revenue. Information provided by specialists and county agents allows stakeholders to make more informed decisions about corn, soybean, and cotton production practices.	
5.	New Sequencing Technology to Model Plant Disease Resistance and Predict Incidence/Severity	Plant disease can be devastating and lead to extensive losses in crop yield and quality. In 2020, 140 million and 14 billion (59.6 billion USD) bushels were produced in Tennessee and across the U.S., respectively. Besides 2-15% annual yield losses, diseases that cause rot lower market value of crop due to contaminants that make the crop unsafe for human and animal consumption. Chemical controls are problematic due to negative impacts on the environment and human health. Plant breeding for race-specific disease resistance oftentimes is successful only for short periods, while breeding for broad-spectrum resistance requires further understanding of genetic-by-environmental interaction (GxE) in order to be successful. A deeper understanding of the genetics of and interaction among soil microbes, plants and plant pathogens is necessary to combat plant disease. By modeling disease resistance and heritability, scientists may better understand how to combat plant disease and improve crop health, sustainability, and yield.	Supporting Food, Fiber, and Energy Systems

		Researchers at UT have developed and validated genomic/metagenomic protocols and created the omeSeq technology to analyze big data in order to predict interactions among plants, plant pathogens, and soil microbes. Using gene sequencing, they produced quantitative profiles at all taxonomic levels for several sweet potato populations and other crops using an exact matching algorithm rather than the imprecise operational taxonomic units (OTU) clustering method. Scientists now are able to broadly profile the metagenome and comprehensively study the biotic interactions and functional microbial hubs and their organisms. These technologies provide researchers with access to information that previously was not available due to technological limitations and cost factors. Using the newly developed technology, the research team has identified genes in sweet potato and corn that have important roles in combatting plant disease, thus providing other researchers with the knowledge necessary to manipulate both plants and the microbial communities in order to mitigate plant disease. The new omeSeq technology is patented but free for public and non-profits use (https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2020243678), while the associated software are open-source and freely available on github (https://github.com/ryandkuster/ngsComposer, https://github.com/B-Kristy/Qmatey, https://github.com/bodeolukolu/GBSapp). Beneficiaries currently include scientists and industry service providers. Scientists are now applying this method to their research as a more robust and cheaper alternative. A service provider is already offering the technology, while other companies are evaluating for kit production,	

		sequencing, and diagnostic services. In addition, eight students (PhD, MS, BS and high school) and two postgraduate researchers received training in microbiome research, three of whom were involved in software development. Students attended various meetings and had the opportunity to present their research.	
6.	Restoring Native Grasslands	Once common, native grasslands have largely disappeared from the eastern U.S. This process has been the result of plowing native grasslands, converting others to introduced grasses, suppression of fires that kept open woodlands open, and urban development. It is estimated that the once extensive woodlands and savannahs, with their rich, grassy understories, are down to less than 1% of their original extent (>131 million acres). Similar losses have occurred with tall grass prairie communities with less than 0.1% remaining where soils and topography were conducive to crop production. Despite these losses, restored native grasslands can make important contributions to improved soil health, sustainable beef and biomass production, greater resiliency to drought, and improved habitat for pollinators and wildlife. It is worth noting that among all species of breeding birds in North America, those associated with grasslands have experienced more severe long-term population declines, for some species more than 80% of their population has been lost in the past 50 years. Likewise, pollinators, critical to our food production and environment alike, have declined markedly in recent decades. Research and Extension efforts are necessary to generate and disseminate new knowledge about best practices for restoring and managing native grasslands so that farmers across the eastern U.S. may become aware of profitable, sustainable production options for their land.	Supporting Food, Fiber, and Energy Systems

		Scientists at UT led a research-Extension integrated project on the development and management of native grasslands in the eastern U.S. Focus was on improved sustainability of grassland ecosystems and the incorporation of native grasses into existing production models in order to improve efficiency, productivity, and sustainability. Research activities evaluated interseeding winter annual forages into dormant warm-season native grass pastures. This work can extend grazing seasons thereby saving farmers money by reducing their reliance on more expensive feeds such as hay or other rations purchased off-farm. Other studies examined cost-effective ways to restore productivity to degraded native grass pastures and use of nurse crops to off-set lost forage production during establishment of native grass pastures. Other research projects evaluated improved pollinator and grassland bird habitat in a working-lands conservation model. This approach does not simply set land aside for conservation purposes, but rather allows grasslands to produce beef as well as both bees and birds. Finally, studies have been exploring how these native grasslands can contribute to carbon sequestration. Indeed, globally, grasslands are one of the most important carbon sinks, capturing carbon from the atmosphere and storing it within the soil. Research resulted in new knowledge pertaining to management of native grasslands. For example, interseeded winter annuals have been demonstrated to produce forage within dormant warm-season native grasses. Just as importantly, preliminary results indicate that no loss of vigor occurs with the perennial native grasses based on this practice. With respect to degraded native grasslands, those that have weakened plants and weed infestations, productivity can be restored by prescribed burning, weed control, or simply resting the stand for one growing season. All these	

		options are much less costly than replanting the pasture. Early results on use of nurse crops are less promising – management of the nurse crops to keep them from shading out the native grass seedlings requires fairly precise timing. Such timing may not be practical for many farmers. On the other hand, the early results from the pollinator and grassland bird projects are quite encouraging about having a viable working lands conservation model. These studies are showing excellent persistence of pollinator plants in native grass pastures and a high degree of use of native grass pastures by bobwhite quail. The team shared the research results with farmers, extension professionals, USDA field staff, the conservationist community, and other research scientists through in-service training sessions, field days for producers, popular and trade articles, professional meetings, video curricula, and scientific papers published in peer-reviewed journals. With this new knowledge, farmers in the eastern U.S. can make informed decisions about establishing native grass forages more reliably, avoiding lost forage production during the seedling year, extending grazing seasons through over-seeding winter annual forages into native warm-season grass pastures, and how to simplify grazing management of native grass pastures. In the long term, when taken together these innovations have the potential to reduce fertilizer and lime bills, reduce impacts from drought, improve beef production per acre, and improve environmental health throughout the eastern U.S. Additionally, four PhD students and three post-docs received training from this project.	
7.	Species and Variety Evaluation to Promote Cover Cropping in Agroecosystems	Cover cropping is an important agronomic practice to improve the health and productivity of the agroecosystem. Cover crops help control erosion, promote soil health, control weeds, pests, and disease, and promote	Supporting Food, Fiber, and Energy Systems

		biodiversity. Research has focused on a select number of cover crop species and their impact on the agroecosystem. Data exploring the breadth of potential cover crop species and the variation of varieties within species is extremely limited. Identifying species and varieties that are well-adapted both regionally and to specific production systems will encourage continued growth in adoption of cover cropping as a practice and will further expand on the ecosystem services that this practice can provide to crop production systems. An integrated team of research and Extension scientists at UT conducted field studies on cover crops at the species and varietal/accession level under different row crop production systems. The team collected data pertaining to soil health, nutrient cycling, weed suppression, insect populations, biomass yield, and forage quality. The team shared project results with Extension agents, producers, and scientists through in-service trainings, field days, an industry/production event, an Extension publication, popular press article, scientific journal articles, and poster presentations at professional conferences. Research revealed that significant variation exists both among and within cover crop species. Species and varieties that were well-adapted to both regionally and to specific crop production systems were identified. The team shared this new knowledge with producers in order to encourage them to adopt cover crop practices and allow them to be more successful in maximizing potential benefits. Extension agents, producers, and scientists benefitted from the new knowledge gained from this project. Graduate students benefitted from	

		experience in breeding, agronomy, and scientific communication. Producers benefitted from better understanding of which species and varieties of cover crop best fit their production systems and are most likely to improve profitability and ecosystem health.	
8.	Development of Sustainable Soilborne Disease Management Strategies for Nursery Production	The production and sale of woody ornamental crops is a big industry in the US, exceeding $5.1 billion in 2016. Nursery producers are vulnerable to losses due to root and crown rot diseases caused by soilborne pathogens. In 2015 these losses were estimated to be approximately 5% of the farm gate value for field and container nursery production. One of these soilborne pathogens, *Phytophthora nicotianae,* can infect 255 genera in 90 families, and accounts for billions of dollars in crop losses annually worldwide and is a leading cause of losses in commercial nursery production. The loss of methyl bromide as a soil fumigant prompted the search for other ways to control soilborne diseases. Nursery producers and university representatives have determined root and crown rots resulting from pathogens like *Phytophthora* spp. as their most important concern in nursery production. To develop new options for the control of this disease, Tennessee State University researcher Dr. Fulya Baysal-Gurel and her colleagues assessed the use of cover crops in the Brassicaceae family to control *Phytophthora nicotianae* in boxwood production. Specific cover crops studied include arugula 'Astro', brown mustard 'Kodiak', mighty mustard 'Pacific Gold', green mustard 'Amara', rape 'Dwarf Essex', turnip 'Purple Top Forage', and yellow mustard 'White Gold'. To test the potential for disease control, once the cover crops flowered, they were chopped and incorporated into the artificially inoculated soil, then covered with a polyethylene film for 30 days. After the 30-day period, boxwoods were planted into the plots and	Supporting Food, Fiber, and Energy Systems

		monitored for three months for disease occurrence, incidence, phytotoxicity and defoliation. Root systems were assessed for Phytophthora root rot disease severity. Over a two-year period, they found that most of the cover crops, in conjunction with soil solarization, were effective in controlling Phytophthora root rot in boxwoods by as much as 50% compared to the non-treated, inoculated control. Farmers have been slow to adopt sustainable biofumigation strategies because of concerns over efficacy, economic cost, and compatibility with their production practices. The results of this research will help to promote the adoption of biofumigants by documenting their effects in multiple nursery systems and demonstrating that using cover crops as a biofumigant, in combination with solarization, can be an accepted, sustainable field-grown nursery production systems for nursery producers in the Southern region.	
9.	Eco-friendly Control of Plant Diseases	Fungal pathogens cause major limitations on agricultural production. In the US, annual losses are estimated at $21 billion per year. This cost expands to $23.5 billion when the cost of controlling these pathogens is included. The development of disease management strategies has relied heavily on conventional fungicides, but these strategies come with concerns about toxicity hazards to humans, non-target organisms, environmental contamination, and development of fungicide resistance. The development of disease-resistant plants is difficult due to the complexities of pathogen/host interactions, and is not always a permanent solution. There is a need to increase the diversity of eco-friendly products that are effective in disease management and are safe to human health, non-target organisms, and the environmental. Using microorganisms to control plant disease is an attractive strategy for combating plant diseases. These	Supporting Food, Fiber, and Energy Systems

		organisms, called biological control agents, can help plants fight disease infection without the negative side-effects of chemical fungicides. Scientists at Tennessee State University have conducted research to identify biological control agents using tomato and dogwoods as model plants; evaluating the control of Phytophthora root rot in tomato and Powdery Mildew in dogwood. Concurrent research was preformed to develop easy, efficient methods to apply the microorganism to plants. This research has identified four organisms that provide control that is as good as, or better than, chemical fungicides for Phytophthora root rot in tomato and Powdery Mildew in dogwood. These organisms also have the benefit of promoting plant growth. Methods were developed that permit growers to easily apply the beneficial organisms and ensuring the organisms were well-established on the plants. Other research is being conducted to measure the effectiveness of the beneficial organisms when plants are grown under various environmental conditions. Products of this research have great potential to reduce pesticide use and therefore reduce toxicity hazards associated with agrichemicals. Use of the products developed in this research will not only save producers money in controlling diseases, but will also improve worker safety and reduce the environmental impacts of chemical fungicides.	
10.	Developing a New Drought-resistant Crop for Southeastern Farmers	Grain amaranths are a new crop for the Southeastern region of the USA. They have an advantage of being very drought tolerant and having C4 photosynthesis. Alternative row crops are needed by Southeastern farmers who rely on a small group of species, most often corn, soybean, and cotton. This situation is acute in Tennessee where most acreage that is not in forest or pasture is planted with corn, soybean, or cotton. Crop improvement	Supporting Food, Fiber, and Energy Systems

		efforts by private companies concentrate almost exclusively on the high-acreage species that are already commercialized, as such, most efforts in the development of new crops fall to public sector breeding programs. Grain amaranth seeds are highly nutritious due to the percentages of protein, fiber, and starch, plus the balance of amino acids contained in their grain. The crop is also considered healthful because it is gluten-free and a whole grain. In addition, the seed can be popped, milled, or boiled like Quinoa. Research at Tennessee State University is evaluating amaranth germplasm for the best genotypes. Program goals are to multiply seed for favorably adapted amaranths and assay diversity and adaptation to heat stress. New varieties will be developed using classical and biotechnology-based breeding techniques. In addition, crosses are being advanced between the three major species of grain amaranths and between A. cruentus, A. hypochondriacus and wild species. This will produce grain amaranth varieties available for growing conditions in Tennessee and across neighboring states. Four genotypes have been identified as varietal releases for Tennessee. In addition, the fertilizer requirements associated with the genotypes have been established. Farmers are being informed about this new crop through site visits, a web site, and publications and pamphlets. The establishment of grain amaranths as a viable rotation crop in the Southeast will improve the overall health of the farming ecosystem. In addition, in the short term, as many new crops fill niche markets of consumers willing to pay more for the novelty and better nutrition presented by the new crops, producers may realize improved income from this new crop.	

11.	Providing New Income Opportunities for Southern Limited-resource Animal Producers	Meat goats are an emerging livestock class that offer US farmers a new option for on-farm income. The US has been a net importer of goat since 1991. Imports have increased over 500%, from 142 tons in 1987 to 10,166 tons in 2007. As a healthy red meat alternative, demand for goat meat will likely continue to surge as a larger segment of the US population becomes familiar with the product. Meat goat production has become an attractive industry among limited-resource producers and serves as a domestic replacement for goat meat that is currently imported. There is potential for even greater opportunities for this emerging animal industry sector, provided that ample research is conducted to reduce the risk of inefficient production practices. A persistent problem faced by meat goat producers is the lack of research-based information to use in decision-making when starting or evaluating their operations. Tennessee State University has an established meat goat research program that examines different feeding and breeding practices used in meat goat production. The overarching goals of the program are to determine if particular management decisions will have a positive or negative impact on animal performance and farm profitability. In follow-up surveys of 140 producers that received educational training based on TSU research, 18% of producers saw a 20% or greater improvement in production efficiency, 29% reported a greater than 20% increase in herd health, and 21% saw a greater than 20% improvement in their overall profitability. Producers overwhelmingly rated their experience with the programs as beneficial, over 90% said the experience was excellent.	Supporting Food, Fiber, and Energy Systems

12.	Crop Nutrient Stewardship Educational Project	With low crop prices, increasing prices of nitrogen and phosphorus fertilizers, and the contribution of production agriculture to diminished water quality in the Mississippi River Basin, fertility practices need to be reevaluated to better benefit our producers and the environment. Increasing the use of sustainable resource management practices will enable the world to meet present needs while continuously improving future generation's ability to meet their own needs. This can be done not only by lessening our environmental impacts, improving human health, and improving the economic and social well-being of Tennessee's communities, but also by increasing productivity to meet current as well as future food, fuel, and fiber demands. An integrated, multi-disciplinary research, education, and outreach program has been established to develop and disseminate information pertaining to crop fertility practices and associated economic and environmental impacts. We promoted the adoption of profitable and environmentally-conscious resource management practices through presentations at field days, county, and/or on-farm demonstrations, newly-developed publications and/or mass media articles, and on-site visits. The Crop Nutrient Stewardship Workgroup's educational efforts in 2020 to promote nutrient use efficiency in Tennessee have resulted in the following impacts (with 38% of counties reporting): • 1120 producers assessed nutrient needs by conducting soil sampling on approximately 449,000 acres; and • 821 producers utilized UT fertility recommendations on approximately 228,000 acres.	Enhancing Biodiversity and Environmental Quality

		By assessing nutrient needs through soil sampling and analysis, 1120 producers potentially reduced fertilizer costs by $18.98/ac and 8,900 tons of excess P2O5 from potentially moving offsite and causing environmental degradation on over 449,000 row crop acres. By utilizing UT fertility recommendations on approximately 228,000 acres, 821 producers had a potential reduction in P2O5 fertilizer costs of $17.77/ac as well as more than 18,800 tons of P2O5 that could move offsite and have negative environmental consequences. The Crop Nutrient Stewardship Educational Project recommended practices have improved crop fertility on over 677,000 acres for an economic impact of over $12.5 million	
13.	Evaluation of Optimum Lighting Techniques in Controlled Environment Agriculture System	The fruit and vegetable industry is important to Tennessee's economy with the state's vegetable, melon, and fruit farming valued at $115.8 million in 2017. Just as important, the industry provides healthy, local food products to customers across the region. Due to stress from climate fluctuations, controlled environment agriculture (CEA) systems including greenhouses and indoor farms can be suitable alternatives to farm production of fruits and vegetables. The advantage of CEA is that it can provide plants with the optimum conditions to maximize growth and nutritional quality. Research and outreach are necessary to optimize CEA techniques such as light quantity and quality in order to help growers achieve the best results at minimum cost. If growers can provide the proper amount of light needed to maximize plant growth and quality, they can grow a high-quality crop faster and thus more crops in a given growing season. Using only the amount of extra light needed (and not more) would be more economical for the grower and provide higher quality food for consumers. Similarly, determining the optimum light quality in which to grow CEA plants is	Enhancing Biodiversity and Environmental Quality

		advantageous. Utilizing energy efficient, narrow band LED lighting for crop production has the potential to reduce energy inputs, meaning growers could produce the same yield with less energy inputs when supplemental lighting is required to grow the crop due to insufficient sunlight in unfavorable growing seasons. UT researchers conducted experiments in a greenhouse to evaluate the effects of specific ratios of narrow-band blue/red Light Emitting Diodes (LEDs) on greenhouse hydroponic basil (Ocimum basilicum var. 'Genovese') biomass production and edible tissue nutrient concentrations across different growing seasons. A total of eight treatments were used: one nonsupplemented natural light (NL) control, one high pressure sodium vapor (HPS) treatment, and six LED treatments with different progressive blue/red ratios. Each supplemented light treatment provided 8.64 mol·m−2·d−1 (100 µmol·m−2·s−1, 24 h·d−1). LED treatments had more fresh biomass and dry biomass for the individual main stem, shoots, and leaves of each plant at varying levels. In comparison to the other treatments, LED treatments resulted in greater height and main stem diameter. Some essential nutrient concentrations were impacted by the HPS and LED treatments and growing season. An energy analysis revealed that on average, narrowband blue/red LED treatments were three times more energy efficient at increasing biomass over HPS. The rate of electricity consumption to biomass increase varied across LED treatments, which demonstrates that basil uses different blue/red narrowband ratios at varying efficiencies. This experiment shows that spectral quality of both supplemental sources and natural sunlight impacts primary metabolic resource partitioning of basil.	

		Data revealed new knowledge about the amount of light that plants need and the best type of light in order to maximize growth and nutritional value. By using narrow band LED lights, the team demonstrated an increase in the human nutritional value of some specialty crops grown in CEA. However, more research is needed to optimize this impact on the nutritional quality of the crop while maintaining high yield. The team shared this new knowledge about CEA systems through courses on greenhouse management, work with Extension specialists and agents, and through training sessions with growers. Producers now are better informed about optimal, efficient lighting techniques to grow crops in controlled environments. The optimum quantity of light and quality of light vary among crops; the team continues toward the goal of optimizing all the factors for a broad range of crops that will benefit CEA growers in and around Tennessee in order to help maximize yield, nutritional value, and profit. In addition, five students – 1 PhD, 2 MS, and 2 BS – students were involved in this project, one of whom published two manuscripts based on the research.	
14.	Development of GIS Application for RUSLE2 Soil Erosion Prediction Tool	Stormwater negatively impacts the environment through soil erosion and contamination of river and stream waters. For example, in the most recent EPA report (2014), about half of Tennessee's miles of rivers and streams were considered to be sufficiently impaired to prevent full usage, and 45% of those impaired miles were caused by excessive sediment. An additional 18% of those miles were impaired by contaminants often associated with sediment. Stormwater Control Measures (SCMs) are used to minimize erosion and sediment delivery from disturbed lands such as agricultural lands, construction sites, forestry settings, and urban areas. Determining the success of SCMs in these settings is difficult to measure, therefore	Enhancing Biodiversity and Environmental Quality

		effectiveness is hard to gauge. Also, factors such climate, topography, geology, and soils make each site different, so the most appropriate SCMs can vary from site to site. In order to effectively estimate the value of SCMs, it is necessary to research and develop better techniques for measuring SCM effectiveness, and incorporate this information into existing modeling technologies to improve site-specific selection and design while accounting for installation and maintenance. This incorporation of site-specific information is best done using Geographic Information systems (GIS), where much of the necessary information can be found in existing databases. If this research is successful, SCMs can be properly selected, reducing the impacts of excessive runoff and contamination of river and stream waters while minimizing costs and negative impacts on productivity. UT researchers have continued development of the Revised Universal Soil Loss Equation (RUSLE) soil erosion prediction model as a GIS interface, thus greatly enhancing its utility. Originally developed as RUSLE1.06 in 1996, this tool was enhanced through a collaboration of UT researchers and USDA-Agricultural Research Service and USDA-Natural Resource Conservation Service scientists and field personnel, resulting in the release of RUSLE2 in 2008. RUSLE2 is currently used by the USDA and governments around the world to assess erosion and inform public policy, and by land managers in agriculture, mining, construction, forestry, and stormwater management to make better management decisions. Stormwater professionals also use RUSLE2 to compare stormwater management alternatives in order to choose the option that best fits their needs and situation. The primary effort to include RUSLE2 in a GIS environment has been a collaboration between UT and USDA-ARS, with substantial beneficial feedback from USDA-NRCS.	

		The application of RUSLE2 in GIS systems expands knowledge of erosion prediction and enhances the tool's usefulness for large-area sustainable management for both government officials and private stormwater professionals. The GIS application allows for far easier and more accurate modeling of field-scale erosion and sediment delivery. The resulting product combining RUSLE2 into GIS has been used in the University of Wisconsin SNAP nutrient management tool, in the Purdue University MMP manure management tool, by several USDOE National Lab, projects looking at harvesting of agricultural biomass for bioenergy, and by several state agencies (e.g., CALTRANS) for controlling erosion on construction sites. These advances have resulted in examination and use of a far broader range of SCMs than in the past, allowing each manager to select the best option for their specific site and situation. The GIS application of RUSLE2 benefits government agencies and stormwater professionals worldwide. When added to its more common uses by USDA-NRCS and other agencies for agricultural conservation planning, it is estimated that RUSLE2 is used somewhere between 2000 and 5000 times per day across the US. In addition, these activities resulted in two MS degrees for Computer Science students at Arkansas State University, and in class materials for multiple computer science and natural resources undergraduate and graduate classes across the country.	
15.	New Technology in Biofuel and Chemical co-Products Engineering	Research shows that there are many advantages to biobased fuels compared to fossil fuels, from renewable resources to clean energy, yet technological issues and high costs prohibit the full adoption of biobased fuels. One way to reduce the cost of biofuels is to derive high-value chemical products from the biomass similar to petroleum co-products such as gasoline, diesel fuel and fuel oil. Biomass feedstock from sources such as	Enhancing Biodiversity and Environmental Quality

		agricultural waste biomass, energy crops, and ocean biomass has the potential to compete with fossil fuels because it provides clean fuels as well as value-added chemical products with less CO2 emission. The booming biodiesel industry in the U.S. and worldwide has generated a massive amount of crude glycerol as by-product. How to efficiently utilize the glycerol by-product is a great challenge. Producing acrylic acid from glycerol appears to be one of the most promising ways to add value to the biodiesel value chain for a sustainable future of biodiesel. Research and development in biorefinery techniques are necessary to optimize the production of biofuels and chemical co-products for maximum efficiency and cost-effectiveness. UT researchers developed a new process to catalytically convert glycerol to acrylic acid and then established computer simulation models to analyze the energy efficiency and estimate production costs at different scenarios. Analysis focused on the feasibility of producing acrylic acid in connection with biofuel production in the context of a circular economy. Variable analysis in response to the market value of glycerol, the source and cost of carbon dioxide recycling, and the changes in process scale and conditions were also considered. The techno-economic assessment results indicate that co-production of acrylic acid with an intermediate-sized biodiesel plant could be economically feasible, contributing to bioeconomy and circular economy. This newly developed biobased technology has created new knowledge in process modeling and production cost estimation that can help biofuel producers and investors assess potential economic feasibilities, bottlenecks, and operation targets for process improvement, and identify	

		further research and development effort requirements. The study pointed out that future development of this biobased technology should consider cascading processing in conjunction with emerging Carbon Capture and Utilization or Recycling (CCU or CCR) Technologies that can efficiently provide CO2. For example, ethanol fuel is already a part of bioeconomy; a typical ethanol plant producing 50 million gallons of ethanol per year also produces approximately 150,000 metric tons of high-purity CO2 annually, which could be connected with acrylic acid production. New biobased technologies are emerging as scattered dots, and the results here would help to connect the dots for the development of cascading and integrated technologies towards a circular economy. Project results were presented at professional conferences and peer-reviewed journals to an audience including oil chemists, biodiesel industry, biofuel and bioproducts researchers, and chemical companies seeking transition to bio-based products, etc. Concepts of integrated biorefinery and process modeling were incorporated into graduate and undergraduate level classes.	
16.	Enabling the Conservation of and Endangered Species in Tennessee	The Hellbender (*Cryptobranchus alleganiensis*), also known as the Hellbender salamander, is a species of aquatic giant salamander native to swift river ecosystems in the eastern and central United States. Hellbenders, which are the largest salamander in the western hemisphere, employ an unusual means of respiration (through skin folds), and as such are heavily dependent on abundant, free-flowing, clean water. Because the Hellbender relies so heavily on clean water, any changes in water quality can have negative impacts on Hellbender populations, making this animal a good indicator species for water quality.	Enhancing Biodiversity and Environmental Quality

		To help monitor and preserve the quality of watersheds in Tennessee, scientists and students from Tennessee State University, with colleagues at Lee University, The Wilds, and the Nashville Zoo at Grassmere used a new technology called Environmental DNA (eDNA) analysis to evaluate the population status of the Eastern Hellbender. TSU researchers collected and filtered water samples, which were tested for the presence of Hellbender DNA. As these animals are quite rare and difficult to detect in nature, this technique provides an efficient and less invasive way to detect the species. This information was used to develop Hellbender distribution maps. Since 2016, over 280 sites have been evaluated and include the Duck River, Little Buffalo River, Big Buffalo River, Big Swan Creek, Calfkiller River, Collins River, Red River, Little River, Doe River, Hiwassee River, Elk River, Ocoee River, and associated tributaries. This research was the first effort to obtain Eastern Hellbender eDNA samples in these streams. Results have been used by the Tennessee Wildlife Resources Agency to develop a state-wide Hellbender conservation plan for Tennessee, which identifies local watersheds that will be conserved or managed for the long-term protection of the species. In addition, this plan will not only protect and provide knowledge on habitats currently occupied by this endangered species, but will also provide an additional means to preserve and increase the number of healthy streams that provide clean water for recreation and consumption.	
17.	Supporting and Expanding Agricultural, Food, and Forest Product Exports in Tennessee	Tennessee's agricultural production and forest resources depend on international trade and foreign markets for sales. According to the U.S. Department of Agriculture, more than 20% of U.S. farm and food products are exported. For a product like cotton, which is the leading export for Tennessee ($680 million), exports are as high as 75% of total production. In	Enriching Our Economy

		2020, Tennessee's agricultural and related product exports were $2 billion and went to over 130 countries. According to U.S. Department of Agriculture, every $1.00 of food and agricultural exports results in another $1.30 in business activity. This indicates that Tennessee's agricultural, food and forest product exports overall economic impact exceeds $4 billion. Therefore, supporting and expanding these exports are important to the state's overall economy. UT Extension's has developed a state-level and regional education and outreach program on international trade and the impact of policies and foreign markets on commodity prices and farm sales. In-service trainings, organized conferences, county and multi-county meetings, producer seminars, popular press articles, Extension publications, and consultations have all been used to disseminate applied research, information, and educational materials to producers, decision makers, and state and national officials such as the Tennessee Commissioner of Agriculture and USDA policy makers in Washington, D.C. All of this was accomplished through 29 reported activities, resulting in 1,408 direct contacts and 412,500 indirect contacts through mass outreach and web-based publications. An important impact of this program is the knowledge gained by direct contacts. Based on before and after surveys, average knowledge before trainings was 2.7, whereas after-training knowledge averaged 4.3 (both are based on a 5-point scale). Over 90% of meeting participants ranked the information provided by the UT Extension as very or highly useful, which are the highest rankings on post-meeting surveys.	

		Another major impact is the direct support that UT-TSU Extension provides to the Tennessee Department of Agriculture (TDA) trade promotion program and international marketing activities. According to TDA, their export promotion and marketing activities resulted in $2.5 million in additional export sales for Tennessee, which is an overall economic impact of $5.8 million (assuming the USDA's multiplier). According to TDA, a conservative estimate of Extension's contribution is 5%, which is based on specialists giving periodic trade updates to senior staff/industry partners to inform decision making, updates on the impacts of COVID-19 on Tennessee agricultural and forest product exports, leading the effort in writing a USDA proposal to fund Tennessee forest product marketing activities in Vietnam, and co-organizing the 2020 Mid-South Agricultural Trade Conference, which is cosponsored by TDA. Accordingly, Extension's impact specific to TDA trade promotion activities is $287,500. UT Extension activities specific to supporting TDA trade promotion ($287,500) assist in supporting and expanding international trade for all Tennessee farmers, land owners, and agribusinesses, which was valued at $2 billion in 2020.	
18.	Tennessee Row Crop Risk Management and Marketing	Tennessee producers have many tools available to mitigate the production, financial, and marketing risks they face (crop insurance, futures and options, marketing contracts etc.). Use of risk management and marketing tools improve the financial stability and long-term viability of the farming operation. Increased cost of production (fertilizers, chemicals, seed, fuel and labor) and low profit margins requires row crop producers to actively seek out alternatives that can mitigate risk and enhance profitability.	Enriching Our Economy

		A state-level education and outreach program has been established to develop and disseminate information about risk management and marketing alternatives to assist row crop producers in improving profitability and mitigating production, financial, and marketing risk. Field days, grain conferences, county and multi-county meetings, popular press articles, Extension publications, personal contacts, and online meetings have been used to disseminate applied research and educational materials to row crop producers In 2020, Extension educational efforts promoting the adoption of risk management and marketing tools to mitigate production, financial, and marketing risk and improve net returns resulted over 4,000 producers and agriculture industry personnel being educated through in-person or virtual meetings, 36 popular press articles, 9 extension publications, and an online decision aid. The program resulted in over 4,000 producers and agriculture industry personnel being educated through in-person or virtual meetings. A sample of producers attending meetings indicated an average direct economic benefit of $4,700 per operation by participating in the program.	
19.	Consumer Economics	The COVID-19 pandemic has created a money crunch for many Tennessee families. Reduced work hours, furloughs, and unemployment threaten financial livelihoods forcing families to reevaluate normal habits of earning, spending, and saving. Prior to the pandemic, GOBankingRate (Anderson, 2019) found that 59% of Tennesseans said they had $0 savings, and 16% reported having less than $1,000 in savings. The financially fragile state of many Tennessee families before the pandemic has been exasperated by the current economic climate.	Enriching Our Economy

		When COVID-19 hit, over 800,000 Tennessee households were already one emergency away from a financial crisis (United Way of Tennessee, 2020). As the pandemic has continued, some Tennessee families face challenges in meeting their basic household needs. Navigating child care needs, obtaining adequate food resources, and paying for housing costs are top barriers currently facing both rural and urban Tennessee families (United Way of Tennessee, 2020). In Tennessee, unemployment claims remain high on historical levels. As of December 2020, Tennessee had seen 936,214 initial unemployment claims in the last 38 weeks. While claims decreased substantially after the initial government-imposed lockdowns in the spring of 2020, claims began to slightly increase toward the end of 2020 (Tennessee Department of Labor and Workforce Development, 2020). The unemployment rate for Tennessee in November 2020 was 5.3%; up from 2019 which fluctuated between 3.2 and 3.5 percent. Though the economic outlook for Tennessee looks positive, Tennessee families can expect recovery from the pandemic to be sporadic marked by periods of growth and stagnation (Economic Report to the Governor, 2021). UT and TSU Extension Consumer Economics programming continued its focus on (1) training citizens, both youth and adults, in sound basic financial practices, (2) encouraging Tennesseans to save to build assets over their working lives, and (3) encouraging individuals and households to reduce dependence on credit and discharge debt. One hundred forty Agents and Specialists from all three UT and TSU Extension program areas conducted Consumer Economics programming.	

		Consumer Economics education activities are conducted through bankruptcy education, homebuyer education, personal finance training for teachers, saving education for adults and youth, and financial education simulations for youth. Programs were modified by specialists and agents to continue meeting the educational needs of consumers--Money Minute videos, online personal finance teacher training, and online adaptation of On My Own, are just a few. Since much of 2020 required modifying delivery methods with creative solutions, direct contacts by agents were down. However, contacts through social media and web delivery of Consumer Economics educational material increased dramatically. Agents reported 23,190 direct educational contacts, compared to 96,000 in 2019, through group meetings, programs, and other direct methods. Agents reported 1,921 contacts via on site visits, 15,667 in personal visits, 324,350 digital contacts, and 5,483,717 through mass outreach, totaling 5,848,845 total contacts by employees. Agents logged a total of 15,191 hours in financial education programming with 32,156 additional hours logged by volunteers. Among the most successful learning and behavioral outcomes for adults participating in Consumer Economics programs were: • 87.9% (n=1,337) identified resources for meeting the needs of their household. • 96.7% (n=1,771) evaluated their housing options based on what they needed and could afford. • 94.4% (n=1,744) better understood basic insurance needs. • 94.4% (n=1,182) better understood credit reporting and scoring. • 94.7% (n=1,557) identified ways to reduce spending.	

		• 99.8% (n=1360) successfully completed homebuyer education requirements. • 91.6% (n= 1,290) understood the dangers of using too much credit. • 96.9% (n=1,252) learned who to pay first if they can't pay everything. Three months after participating in a Consumer Economics Extension program, participants reported the following: • 94.7% (n=800) followed a spending plan. • 80.4% (n=881) checked their credit report at annualcreditreport.com. • One thousand three hundred sixty prospective homeowners successfully completed homebuyer education requirements of which 938 purchased a home resulting in $143,397,051 in loan activity. The percentage of Extension clientele reporting saving rose to 80% in 2020 from 78% in 2019. As a result of UT Extension's Consumer Economics programming, the estimated economic impact of clienteles' savings for six months totals $2,897,183.	
20.	COVID-19 and Cotton Import Demand in China	U.S. agribusinesses and producers rely on both domestic and international markets for sales and thus are impacted by U.S. and international policies, regulations, and economies. The COVID-19 pandemic has led to significantly reduced spending on cotton products worldwide. China, the leading cotton importer and clothing and apparel exporter, has a reduced demand for cotton from exporting countries such as the U.S. Market research on the demand for cotton during the COVID-19 pandemic led to increased knowledge about U.S. cotton exports and enabled stakeholders,	Enriching Our Economy

		including producers and investors, to make informed decisions to reduce financial losses and mitigate risk. UT researchers examined the Chinese demand for imported cotton by product form (raw cotton and yarn) and by source (e.g., U.S., India), as well as the dynamic price relationships across countries. They reviewed data published by Trad Data Monitor, Inc., the U.S. Department of Agriculture, and the U.S. Department of Labor. Using year-to-date trade, demand estimates, and price forecasts, the team assessed the impact of COVID-19 on Chinese imports and the countries supplying this market. Researchers suggested that the impacts of COVID-19 on Chinese cotton imports through the end of 2020 would remain similar to the first half of the year or may improve slightly depending on the impact of manufactured-product prices on imports. This research has increased understanding of the potential impact of the pandemic to U.S. and Tennessee agriculture. With the signing of the U.S.-China Phase One Trade Agreement in January 2020 and retaliatory tariff exemptions by the Chinese government in March 2020, the expectations for U.S. cotton exports to China in 2020 were significantly higher than the level in 2019. Results suggest that Chinese imports of U.S. cotton in 2020 will fall well short of this goal. The research team published their findings in *Agribusiness: An International Journal* and thus will reach a wide audience of agribusiness professionals. The potential influences of an unforeseen global pandemic on the world market identified in this study could help U.S. cotton producers and	

		agribusiness plan their production and investment decisions accordingly to address related issues in the future.	
21.	COVID-19 Rapid Response for Garden Centers and Nurseries	The COVID-19 pandemic is a threat to human life, human health, social stability and economic growth. Independent garden centers are part of the supply chain of the green industry. Disruption of these garden centers would cause harm to the supply chain of live plants, and health of gardening communities large and small. During the 2020 Spring COVID-19 pandemic, nursery and garden centers were open as essential businesses. Larger garden centers and nurseries changed to online and phone orders for curbside pick-up or home delivery. In small rural towns however, many garden centers do not have the resources for online sales, and local customers are used to on-site shopping, making them very vulnerable to the spread of the virus. There is a need to provide a workable system that will protect these garden centers from potential COVID-19 threats and provide a safe shopping place and experience for customers. Researchers at Tennessee State University have partnered with biotech business partners do develop a solution backed by science to help protect these smaller businesses as the planting season arrives. The project uses a number of strategies to accomplish this goal. First is diagnostic antibody testing to identify employees who carry COVID-19 antibodies. Second is the design of automatic infrared temperature stations customized to the outdoor settings of garden centers to measure customer's temperature; if a customer has a fever, that person would be discreetly re-directed to a different zone in the store to shop for their needs. Store associates would be on hand to help those customers find what they need. Third is to implement Best Management Practices to ensure the business is in compliance with guidelines from respective government agencies. A	Enriching Our Economy

		second phase of the project focuses on Extension activities involving development of the technology-enhanced education packages for promoting the adoption of all the safety measures across Tennessee and nationwide. COVID antibody tests were performed on workers at participating garden centers. Those employees who have developed antibodies were available to help customers who did not pass the initial temperature check when they walked in. This allowed business owners to use acquired immunity to their advantage and keep their business functioning. Business managers were educated about federally mandated safe business practices during a pandemic including social distancing rules and the wearing of masks and gloves. The redesign of the presentation of their goods was suggested so customers could freely walk among products and maintain social distancing from other customers. There is a need to provide a workable system that will protect these garden centers from potential COVID-19 threats and provide a safe shopping place and experience for customers.	
22.	Creating Economic Opportunities for Small and Medium Sized Farmers	Recent data indicate that 90% of farms in the US are considered small family operations, however these small operations accounted for only 24% of the value of production. Economic pressures on small and limited-resource farmers mean they need ways to improve profit without incurring too much cost. One of the ways small farms may improve income is by adopting the latest agricultural innovation technologies for on-farm product processing. There are small scale on-farm profit improving ventures affordable to small and midsized farmers. The adoption of new technologies such as alfalfa palletization will have lasting impact on the livelihood of livestock producers. Alfalfa pellets are considered as a renewable, high-quality feed for livestock.	Enriching Our Economy

		Researchers at Tennessee State University conducted surveys to identify problems, issues, barriers and opportunities to improve efficiency and productivity of small farm enterprises. Variables considered were affordable start-up costs, and range of profits considering price, yield and input costs variations. A producer survey was conducted to determine current knowledge, opportunities and barriers, and willingness to invest for low-cost technologies for product processing. Small scale alfalfa pellet processing units were identified as applicable for small and mid-sized production systems and performed well in cost-benefit analysis. The crop budgets and farm financial decision making tools were developed for better decision making. Growers can earn higher profit by shifting to alfalfa pellet processing. The investment of $2,500 - $3,000 for a small scale processing plant can improve farm profit in the range of $80 to $137 per acre depending on the scale of operation. Results identified price and yield as key variables affect profit hence producers need to pay special attention price and yield variations. About 62% of the growers contacted showed interest in learning new investment opportunities.	
23.	Skill Up Tennessee	On average, almost 870,000 Tennesseans participated in the Supplemental Nutrition Assistance Program (SNAP) each month in 2020. Based on 2018 data, average median income of households on SNAP was $19,917 which is one-third the average median household income of non-SNAP households. Seventy-five percent (75%) of SNAP households had 1 or more workers, yet 53% were below the poverty level. A low level of education is a barrier for many of these individuals. Knowledge of jobs available, the skills needed for those jobs, and how to gain those skills is a limiting factor. Cost is an important factor as well, both	Developing Our Workforce

		for direct training costs such as tuition and books and vital supports such as transportation and childcare which often present significant barriers. Low levels of training and education affect individuals and their families as employment opportunities are limited. Middle-skill jobs, or those requiring more than a high school diploma but less than a 4-year degree, are in demand and available with a moderate amount of training. Employers are affected when there is a shortage of workers with the required knowledge, skills, and soft skills necessary to be successful in these jobs. Skill Up Tennessee, UT Extension's SNAP Employment and Training Program conducted in partnership with the Tennessee Department of Labor and Workforce Development, was implemented to help qualifying adult SNAP participants set and reach training and employment goals that lead to self-sufficiency. The program is marketed through partners at the county level, in collaboration with Family and Consumer Sciences Extension agents and Career Navigators (Extension Assistants), to recruit interested individuals for the program. Case management is provided by Career Navigators to help participants address barriers, plan, and pursue training leading to employment. Agents in approximately 75 counties have been trained to participate in the program. Based on SUPER reporting, 172 group meetings, 85 on site visits, 4698 personal correspondence, 141 digital contacts, and 22 mass outreach activities were reported from 24 counties and the Department of Family and Consumer Sciences. Partnerships have been developed with statewide, regional, and local organizations to promote the program.	

		Skill Up Tennessee has connected participants with support and resources to help them gain the training and skills needed for employment. In 2020, three hundred sixty (360) individuals preregistered with 292 of those verified as eligible to participate in the program. Together with those already engaged, 398 individuals from 64 counties participated in the program. Two hundred forty-four (244) participated in vocational/technical training at a Tennessee College of Applied Technology, community college, or other training provider; 61 earned a recognized credential in vocational/technical training, at least 16 have obtained employment, and 38 participated in job retention. Because of the nature of the program this fits the typical pattern of initial recruitment, enrollment in training that can last up to two years, then earning a credential that leads to employment. Supportive services such as tuition assistance, help with the cost of textbooks, and assistance with transportation and childcare were provided as barriers were identified. Based on the most recent data, for every dollar that is spent, the Skill Up Tennessee program adds a total of $1.92 back to the economy. The most recent data (FFY 2019) indicate a total of $656,421 was invested in the Skill Up Tennessee program resulting in economic impact of $1,260,328.	
24.	Tennessee 4-H Workforce Preparation – 4-H STEM	The National Science Foundation's (NSF), "The State of U.S. Science and Engineering 2020," concluded that most Tennessee 4th and 8th graders did not demonstrate proficiency in the knowledge and skills taught at their grade level in science and mathematics. In fact, according to NSF, 8th grade public school mathematics proficiency in 2019 in Tennessee was at 31% (3rd quartile nationally); and 8th grade public school science proficiency in 2015 in Tennessee was at 37% (2nd quartile nationally). In addition, the number of bachelor's degrees in science, engineering, and technology	Developing Our Workforce

		conferred per 1,000 individuals 18-24 years old in Tennessee in 2018 was 16.45 (4th quartile nationally). Although all of these indicators show an upward trend compared to previous NSF reports, there is still much room for improvement. Attention must be paid to introduce students to and encourage an interest in science and other STEM fields at an early age. Barker & Aspray (2006) students oftentimes lose interest in STEM subjects by middle school (Grades 6-8). Early interventions help to create a STEM pipeline for students to major in STEM-related fields and enter STEM careers. UT and TSU Extension made 199,704 direct, and 619,883 digital educational contacts to help youth gain new knowledge, acquire new skills and increase aspirations regarding 4-H STEM. Programs were delivered through 6,836 group meetings and on-site visits, and by 4,904 digital methods, including organized clubs, camps, project groups and school enrichment by Extension 4-H agents and volunteers. Educational programs also occurred by means of personal correspondence (13,956) and mass outreach (128,967). Youth were surveyed to determine the impact of these programs with regards to 4-H STEM. Of the youth who participated in 4-H STEM programs by UT agents: • 941 youth can use specific scientific knowledge to form questions. • 924 youth can ask a question that can be answered by collecting data. • 88 youth can use data to create a graph for presentation to others. • 813 youth can design a scientific procedure to answer a question. • 400 youth can create a display to communicate scientific data and observations.	

		• 359 youth can use models to explain scientific results. • 3,034 youth like experimenting and testing ideas. • 206 youth can use the results of their investigation to answer the question they had asked. • 2,869 youth get excited about new discoveries. 2,491 youth report they now like science. • 2,097 youth now do science activities that are not for school. • 2,000 youth like to see how things are made or invented. • 198 youth can communicate a scientific procedure to others. • 181 youth can use science terms to share scientific results. • 1,890 youth report wanting to learn more about science. • 1,799 youth report they are good at science. • 1,451 youth can analyze the results of a scientific investigation. • 1,373 youth would now like to have a job related to science. • 1,125 youth can record data accurately. TSU Agents programmed to youth in the area 4-H Science. Of the youth participating, 400 youth now do science activities that are not for school, 24 youth like to see how things are made or invented, 22 youth report they now like science, and 216 youth report wanting to learn more about science. TSU Agents programmed to youth in the area of communication. Of the youth participating, 844 youth can show enthusiasm when giving a speech, 817 youth report that they have developed confidence to speak in front of groups, 1, 874 youth can select a topic for a speech or talk, 1,717 youth can explain an idea to others.	

		Volunteers contributed 6,409.25 hours of time to 4-H STEM youth work in Tennessee. Using Independent Sector data to calculate the value of volunteer time, Tennessee 4-H, through its volunteers, generated $150,617.38 worth of value to the 4-H STEM program in Tennessee.	
25.	Tennessee 4-H Workforce Preparation – Achieving Goals and Communicating	According to data from the Business-Higher Education Forum and The Conference Board, Inc., employers are reporting young workers lack key skills and attributes necessary for success in today's workplace. This research also indicates companies are asking for young adults who have applied skills in communication, leadership, teamwork and problem solving. Due to the changing nature of the 21st century workplace, Tennessee youth need the skills, experience and confidence necessary to meet its demands and thrive in a high-performance economy characterized by high-skill, high-wage employment. UT and TSU Extension helped youth gain new knowledge, acquire new skills and increase aspirations regarding the life skills of achieving goals and communicating. Tennessee 4-H made 66,174 direct education contacts in achieving goals and 65,624 direct educational contacts in communicating, as well as 530,370 digital contacts in achieving goals and 524,837 digital contacts in communicating. Youth were surveyed to determine the impact of these programs with regards to Achieving Goals and Communicating. Of the youth who participated in 4-H programs the following outcomes were achieved. • 991 youth who are now making plans to achieve their goals. • 850 youth who have put their goal(s) in writing. • 760 youth report that they now achieve goals they set for themselves.	Developing Our Workforce

		• 682 youth have set a goal for their job or career. • 662 youth now set high goals that require work to achieve them. • 493 youth who keep trying if they do not achieve their goal the first time. 411 youth set deadlines to achieve their goals. • 251 youth try to get as much assistance as they can when working toward their goal. • 236 youth have a goal set for their job or career. • 215 youth who work out the details when others set goals for them. 1,821 youth now work to achieve their goals. • 1,479 youth put their goals in writing. • 1,158 youth set high goals. • 1,113 youth break goals down into steps so they can check their progress. • 930 youth are now better listeners. • 580 youth report they can now keep records. • 359 youth use parliamentary procedure to run a meeting. • 355 youth report they have improved photography skills. • 35 now can create on-screen (multi-media) presentations. • 3,451 youth can express ideas with a poster, exhibit or other display. • 2,273 youth are better able to understand and follow directions. • 2,236 youth can now share their ideas through writing. • 2,054 youth can use technology to help themselves express ideas. • 180 youth have knowledge of careers in the communications field. • 149 youth have explored careers in communications. • 114 youth now communicate through a website.	

		• 10 youth report that it is now easier to express their opinions to someone with a different opinion than their own. • 1,678 youth have learned at least five jobs in which communication skills are important. • 1,319 youth report they have learned skills in visual communications. Volunteers contributed 7,477.25 hours of time to 4-H STEM youth work in Tennessee. Using Independent Sector data to calculate the value of volunteer time, Tennessee 4-H, through its volunteers, generated $175,715.38 worth of value to the life skills of achieving goals and communicating in Tennessee.	
26.	EFNEP and TNCEP: Improving Dietary and Physical Activity Behaviors for Limited-Resource Tennesseans	Poor dietary quality and lack of physical activity continue to affect SNAP-eligible Tennessee adults and youth. Increased incidence of diet-related chronic diseases such as diabetes, hypertension and certain cancers are prevalent among this population. Access to healthy food options and physical activity opportunities, along with nutrition education programming and community interventions, are important for helping limited-income individuals and families reduce health risks while managing food resources effectively. In 2020, COVID-19 exacerbated these issues as it exposed large systemic gaps in food resources. In other words, food insecurity rates rose as people became unemployed and food distribution was interrupted by the global pandemic. Through the Expanded Food and Nutrition Education Program (EFNEP) and the Supplemental Nutrition Assistance Program Education Tennessee Nutrition and Consumer Education Program (SNAP-Ed: TNCEP), UT and TSU	Strengthening Our Health

		Extension Family and Consumer Sciences continues to offer nutrition education programming and interventions for limited-resource audiences. The primary objectives of these multi-level, community health programs and interventions were to increase the likelihood that limited-resource persons would make healthy food choices within a limited budget and choose physical activity guidelines consistent with the current Dietary Guidelines for Americans. Youth from preschool to high school and adults from young adulthood to seniors benefited from this work. Social marketing and the use of social media were particularly high this year with limited face-to-face programming options available. Programs were converted to indirect education or online/remote learning through zoom and Facebook live. Trainings for program assistants and agents from the state level included guidance on remaining compliant with grant funding and reaching audiences creatively despite stay-at-home orders. TNCEP conducted direct education with 20,370 adults and youth and contacted 2,098,671 Tennesseans indirectly. UT and TSU Extension's programing with TNCEP resulted in 13,359 Policy, System and Environmental (PSE) changes. Notable TNCEP outcomes include the following: • 28% of youth and adults (1232 out of 4366) increased consumption of vegetables. • 29% of youth and adults (1289 out of 4371) increased consumption of fruits. • 29% of youth and adults (1279 out of 4369) decreased consumption of sugar-sweetened beverages.	

		• 29% of youth and adults (1250 out of 4366) increased time spent in physical activity. • 76% of adults (530 out of 697) improved in at least one food resource management behavior EFNEP. Over 5,470 individuals participated int EFNEP programming. Adults reported saving $17,642 in monthly food purchases EFNEP outcomes. Specific EFNEP outcomes include the following: • 54% of youth and adults (1164 out of 2172) increased consumption of vegetables. • 54% of youth and adults (1177 out of 2169) increased consumption of fruit. • 47% of youth and adults (1025 out of 2168) decreased consumption of sugar-sweetened beverages. • 56% of youth and adults (1206 out of 2159) increased time spent in physical activity. • 80% of adults (1171 out of 1466) improved in at least one food resource management behavior. The economic benefit of UT SNAP-Ed: TNCEP and EFNEP programming is $66,015,350 in reduced long-term health care costs. The total economic breakdown includes $44,515,230 for UT SNAP-Ed: TNCEP and $21,500,120 for EFNEP. TSU Community Nutrition Education Program (TSU CNEP), both EFNEP and SNAP-Education, is in 8 of the 95 counties in Tennessee and focuses on increasing food resource management skill adoption with SNAP-eligible audiences. Through the social marketing and branding campaign	

		"Shop.Cook.Eat. Within Your Budget." TSU CNEP reached 2,394,282 Tennesseans with the program in FY20, with 1,517,955 of these indirect contacts occurring in the second half of the year as a direct result of the COVID-19 Pandemic and moving programming to a virtual education format. SNAP-Education: As a result of attending and graduating a series of 6-8 lessons, comprising of 60-90 minutes each, 335 adults who were pre- and post-tested reported • 62% ate more fruits • 70% at more vegetables • 65% reduced sugary beverages • 75% chose healthy meals • 58% never ran out of food • 75% compare price of food • 56% increase physical activity EFNEP: In 2020 TSU EFNEP graduated 79 adults (6-8 lessons, comprising 60-90 minutes each) and 606 youth (4-6 classes, comprising 30-60 minutes each). Adult graduates from the TSU EFNEP program reported 90% improved diet quality; 66% increased physical activity; 71% improved food safety practices; and 87% improved food resource management skills. Youth EFNEP graduates reported 86% improved diet quality; 50% improved food safety practices; 52% improved physical activity; and 41% improved food resource management skills.	

27.	Healthy Diets for Chronic Disease Prevention and Management	Consuming a healthy diet is essential for people of all ages. Despite the importance of a healthy diet, most people in the United States do not follow dietary recommendations. In Tennessee, average intake of fruits and vegetables, a key component of a healthy diet, is below recommendations. Only 11.1% adults in Tennessee consume the recommended amounts of fruit and only 9.6% of Tennessee adults meeting consume the recommended amounts of vegetables (CDC). A person's food choices are dependent on multiple factors, including personal preferences, cultural traditions, and a person's ability to access and afford nutritious foods. During the COVID-19 pandemic, existing challenges for consuming nutritious foods were exacerbated as many people lost employment, shopped for food differently, and encountered low inventory of food items in stores. Diet-related chronic conditions, like heart disease and diabetes, are highly prevalent in the United States and can be prevented and managed, in part, by making nutritious food choices. These chronic conditions increase risk for disability and early death and are costly, increasing direct healthcare costs, decreasing productivity, and increasing absenteeism from work. Tennessee has the 6th highest rate of cardiovascular disease (11%) and the 4th highest rate of diabetes (13.8%) in the United States (America's Health Rankings). Interventions that help Tennesseans make healthy food choices are important to improve and maintain health for Tennesseans of all ages. In 2020, UT and TSU Extension Family and Consumer Sciences (FCS) reached 6,739,729 adult and youth contacts through nutrition programming. UT and TSU Extension FCS safely conducted in-person and virtual nutrition education programming, providing resources to help	Strengthening Our Health

		Tennesseans choose and prepare healthy foods within their food budgets. Through social media, email, printed publications, television, radio, and other communication efforts, UT and TSU Extension FCS provided information to help Tennesseans make healthy food choices, know how to access federal nutrition assistance programs (such as P-EBT), choose nutritious foods that fit within their food budgets, and locate food pantries in their local communities. UT and TSU Extension FCS helped Tennesseans plan and prepare healthy diets. Through surveys designed for nutrition education programs, participants reported the following dietary improvements. • 3,124 of 3,720 (84%) of surveyed participants reported making dietary improvements that aligned with recommendations in the Dietary Guidelines for Americans, such as eating more fruits, vegetables, and whole grains and drinking fewer sugar sweetened beverages. • 1,364 of 1,863 (73%) of surveyed participants reported planning healthy meals. • 5,879 of 6,532 (90%) of surveyed participants reported preparing healthy meals. University of Tennessee Extension FCS helped Tennesseans manage their food resources for healthy diets. Through surveys designed for nutrition education programs, participants reported they were better able to manage their food budgets and food resources. • 524 of 911 (58%) of surveyed participants reported planning meals to manage their food resources. • 4,907 of 5,259 (93%) of surveyed participants reported utilizing food resource management strategies, such as using coupons and the	

		unit price while shopping, to purchase healthy foods within their budget. UT and TSU Extension nutrition education programs helped Tennessean's make nutritious food consumption an easy choice in the places where people live, work, eat, worship and play by implementing 101 nutrition supports, such as community gardens, across Tennessee communities. The economic benefit of UT and TSU Extension nutrition education is estimated at $22,493 through healthcare cost savings, resulting from dietary improvements that align with dietary recommendations in the Dietary Guidelines for Americans (Calculations estimated from Scrafford et al. 2019).	
28.	Investigations in One Health	The One Health concept recognizes that the health of humans, wildlife, and domestic animals are interconnected with each group having the potential to greatly impact the others. This interconnected health is particularly evident concerning infectious diseases. When one of these groups is impacted by infectious disease the others are at risk, too. Addressing infectious disease – both detection and treatment – with a One Health approach allows experts to control and mitigate health challenges with holistic solutions. Multi-disciplinary researchers united under UT's One Health Initiative have developed electrochemical detection methods for virus and bacteria. The team has developed improved molecular/electrochemical methods to detect virus using a state-of-the-art molecular switch system. They filed a provisional patent application for inventing an electrochemical detection method for pathogens in humans, animals and the environment. The researchers are working toward commercializing the new technique. In	Strengthening Our Health

		collaboration with electrical engineering experts, the new technique is being used for development of sensitive, rapid and portable pathogen detection devices that can be used on site (in field, bedside, pen-side). The improved technique for pathogen detection contributes new knowledge to infectious disease management strategies for both humans and animals, and will expand disease epidemiology. For example, the team is applying the technique for detection of the causative bacteria of Johne's disease and mastitis which are causing a significant economic loss to the dairy industry. The detection and identification of the pathogens in animals and the environment will help the producers to control the diseases while minimizing misuse of antibiotics, thereby improve animal wellbeing and profitability of the farm. The team has also been collaborating with data science/sensor experts to develop an integrated system for mastitis and lameness control through pathogen detection, animal movement analysis, and AI-driven animal management planning. This project will create new knowledge in integration of multidisciplinary scientific findings into an animal management strategy. Once the pathogen detection device (or system) is developed, it will help not only the wellbeing of farm animals but also the profitability of the dairy farm business. Since the new technique is applicable to detection of other pathogens (viruses and bacteria), it will also benefit the food industry, human health, and wildlife conservation in a long-term range.	
29.	Deriving Lunasin with Health-Promoting Properties from Tofu Wastewater to Increase Food Application of Soybean	The U.S. is a leading producer and exporter of soybean – a crop that is important for both economic and health reasons. In Tennessee, soybean has an estimated revenue of $1.7B creating more than 4300 paid jobs in soybean production, soybean delivery, soy biodiesel production, and feed	Strengthening Our Health

		milling. The national soybean sector has an economic impact on the U.S. amounting to almost $116B which is equivalent to more than 0.65% of the U.S. GDP. Soybean is rich in protein with bioactive compounds that have potential health promoting properties. Soybean consumption is associated with reduced risk of cancer and cardiovascular disease. However, there are obstacles to overcome in order to maximize soybean's food application as a source of health-promoting compounds. Soybean proteins contain lunasin, a naturally-occurring bioactive peptide. However, lunasin is not stable during processing and digestion which may lead to peptides and amino acids with fewer health-promoting properties. More research is necessary to understand how certain inhibitors affect the stability of lunasin in order to improve the health benefits of soybean, thus expanding its use as a functional food ingredient. In addition, lunasin has always been isolated from either whole soybean or protein isolate making the process of obtaining lunasin complex and tedious. Another potential source of lunasin is through soybean tofu processing. Tofu processing generates a large amount of waste, including wastewater and residue. More information is necessary about the potential of tofu wastewater as an alternative source of lunasin to simplify the isolation and preparation of lunasin-enriched material, as well as to find use of wastewater to lower the negative impact of the soybean processing industry to the environment. UT researchers partnered with a tofu manufacturing plant in Summerville, TN to develop a commercial-scale method to derive the bioactive peptide lunasin from tofu production using wastewater. Tofu processing produces a large amount of wastewater – approximately 9 kg of wastewater per 1 kg of soybean – and costs about $130 per cubic meter for disposal. Given the quantity of waste and the cost of disposal, as well as the loss of the	

		wastewater's bioactive ingredients, the team developed a functional use for wastewater as a source of the bioactive peptide lunasin. They combined isoelectric precipitation and size-exclusion chromatography to produce a lunasin-enriched material that is at least 80% lunasin. Research data showed that the lunasin derived from the tofu wastewater successfully reduced inflammation and the effects of colitis in mice. The results are the first to report the utilization of tofu wastewater as a source of lunasin that has health-promoting properties. The research team generated new knowledge by demonstrating that the waste generated from a tofu manufacturing plant in a commercial scale can be used as a source of health-promoting peptide lunasin originally isolated from soybean. The lunasin-enriched material obtained demonstrated health promoting properties, thus expanding the use of soybean co-products (in this case wastewater from tofu) as a source of functional food ingredients. With this knowledge, the soybean processing industry will be able to convert a co-product (tofu wastewater) into a high-value lunasin-enriched material that can be sold as a dietary supplement for prevention of inflammation-related disorders. This increased food application is expected to lead to a higher demand for soybean production in the U.S. as well as lower the negative impact of soybean processing plant in the environment. Project results were published in academic journals and shared at professional conferences and public seminars with audiences including scientists, food industry stakeholders, and ingredient specialists. Four graduate students and twenty-five undergraduate students received training in laboratory techniques and activities related to isolation,	

		production and characterization of biologically active peptides and proteins from soybean and sorghum. Students had the opportunity to present their research at national and international conferences and at the University's undergraduate research exposition.	
30.	Enteric Diseases of Food Animals: Enhanced Prevention, Control and Food Safety	Food safety, including the health of food animals, has a significant impact on human health. The CDC estimates that 48 million people get sick with foodborne illness each year. *Campylobacter* spp. bacteria are one of the most common causes of foodborne illness and are linked to autoimmune disorders such as Guillain-Barré syndrome, multiple autoimmune syndrome, inflammatory bowel disease, rheumatoid arthritis, and irritable bowel syndrome. *Campylobacter* and other bacteria are found in food animals, such as poultry, ruminant, and swine; humans are exposed to the bacteria when they consume food products from infected animals. Overuse of antimicrobials (including antibiotic growth promoters) has led to widespread antibiotic resistance which impacts animal health, public health, food safety, and environmental exposure. Controlling bacterial infection in food animals with minimal use of antimicrobials is crucial to improving food safety and reducing the incidents of foodborne illnesses in humans. Scientists at UT researched prevention and intervention strategies to mitigate bacterial infection in food animals. They developed innovative immune intervention strategies by targeting enterobactin, a key molecule utilized by diverse bacterial pathogens to establish infection. The new enterobactin-based vaccine can control a panel of major bacterial pathogens of food animal origins, such as *E. coli*, *Salmonella*, and *Campylobacter*. In a chicken vaccination trial, the vaccine significantly reduced the level of *Campylobacter* in the chicken, providing a novel	Strengthening Our Health

		strategy to control *Campylobacter* bacteria in poultry and humans. In addition to controlling bacteria colonization, the researchers have been developing and validating a new alternative to antibiotic growth promoters. They completed a large pen trial to assess the effects of a non-antibiotic alternative – an inhibitor targeting intestinal bile salt hydrolase – on chicken growth performance and gut health. The team also developed an innovative and cost-effective means to improve viability of probiotics for effective control of intestinal disease. The research team has created new knowledge about the control of bacterial pathogens in food animals which may result in improved animal health and food safety and lead to reduced occurrences of foodborne illness in humans. The research team also utilizes multidisciplinary approaches to address mitigation of antimicrobial resistance by developing innovative antibiotic-free technologies. The research directly addressed the two concerns that prevent animal industries from reducing antibiotic usage: the nutrition concern for feed efficiency and growth rate and the disease concern for preventing and controlling bacterial infections. Thus, the project will lead to effective non-antibiotic strategies that can be practically implemented by poultry producers, resulting in the reduction of antibiotic use and mitigating antibiotic resistance in animal production system. Despite the recognized antibiotic resistance issues associated with antibiotic usage in food animals, animal industries still heavily rely on antibiotics due to the lack of practical and consistent non-antibiotic approaches. An urgent need exists to develop effective antibiotic-free strategies to maintain animal health and productivity. This research project	

		will lead to development of innovative immune intervention and non-antibiotic approaches for immediate adoption and commercialization in poultry and possibly other livestock, thus mitigating bacterial pathogens and antibiotic resistance across the food chain.	
31.	Reducing On-farm Bacterial Contamination of Produce	Antibiotic resistance is one of the major threats to human health and food security. The overuse of antibiotics in animal production is a contributor to the abundance of antibiotic-resistant bacteria in animal manure. When the manure from heavily-dosed animals is applied to farming lands, antibiotic resistant bacteria are introduced into agricultural production and eventually the human food chain. Educating animal producers on the extent of the problem and the proper, cautious use of antibiotics in animal production will help limit antimicrobial resistance from spreading into agricultural lands. Researchers at Tennessee State University have addressed antimicrobial resistance by identifying antimicrobial resistant bacteria and resistance patterns in poultry and cattle farms. This information was used to generate a series of hotspot maps that compare the resistance patterns with the frequency of antibiotic use in cattle and poultry farms in Tennessee and Alabama. Workshops and webinars were also conducted to educate animal producers on the proper, cautious use of antibiotics. The maps produced were at a scale that individual producers could recognize how their actions influence the introduction of antibiotic resistant bacteria into the agricultural system. By using personalized hotspot maps displaying the frequency of antibiotic resistant bacteria in farms, producers are able make informed decisions on the usage of antibiotics. COVID restrictions reduced the ability to educate producers in	Strengthening Our Health

		person. However, through webinars, 19 producers were educated on antibiotic usage in food animals and its impact on mitigating antibiotic resistance; and additionally, 31participants were also educated on alternatives to antibiotics. Materials generated in this program will continue to be used to educate other producers.	

Youth Development Expenditures (dollars)	
State and/or Institution:	**FY 2020 Expenditures:**
1862 Smith-Lever (University of Tennessee)	$1,176,962
1890 Extension (Tennessee State University)	$2,400,000