

# Pennsylvania (Penn State University Park) Annual Report - FY2021

## Report Status: Approved as of 07/08/2022

### Contributing Organizations

---

Penn State University Park

### Executive Summary

---

#### Overview

The College of Agricultural Sciences at Penn State will provide comprehensive support to the residents of Pennsylvania through the activities of the Pennsylvania Agricultural Experiment Station (AES) and Penn State Extension (PSE). We will be responsive to stakeholder needs through translational research and delivery of science-based programs to clientele, but we will also conduct internationally relevant fundamental research that generates baseline data to solve future problems and actively seek new and better ways to communicate our programs to new audiences. Our faculty and staff, partially supported by federal base funding, will effectively leverage this investment against many other funding sources to conduct programs of the highest caliber. We are committed to excellence in research, educating the next generation of agricultural professionals and citizens, and promoting life-long learning among the citizens of Pennsylvania.

Our College's mission is clear: "The mission of the College of Agricultural Sciences is to discover, integrate, translate, and disseminate knowledge to enhance the food and agricultural system, natural resources and environmental stewardship, and economic and social well-being, thereby improving the lives of people in Pennsylvania, the nation, and the world."

#### *Evolving outlook on the future of agriculture*

Agriculture faces challenges of rising energy costs, weather extremes, an expanding human population, environmental degradation, loss of biodiversity, labor shortages, armed conflict, and a lingering pandemic. To help meet these challenges, we developed a conceptual framework based on the science of agricultural sustainability--defined as the integration of natural and social sciences to inform practice and policy for productive, working landscapes, healthy watersheds, and resilient economies. This innovative approach to agricultural research, engagement, and education centers on the impacts and synergies of contiguous rural and urban landscapes. From forests to crops to animal facilities, the location of economically significant agricultural systems in Pennsylvania adjacent to and sometimes within highly populated regions creates distinct challenges and opportunities for the integration of natural and social sciences to inform practice and policy.

A primary component of AES and PSE work in our College is built on the three integrated pillars of sustainable intensification, resilience, and regeneration of agricultural landscapes as solutions to some of the most vexing problems confronting Pennsylvania and similar mosaic landscapes worldwide. We holistically and comprehensively address these critical issues:

- increasing the efficiency and profitability of agricultural production while minimizing environmental impacts
- equipping farmers to absorb and recover from short-term or long-term shocks and stresses to their agricultural production and livelihoods
- optimizing plants, animals, and ecosystems for resistance to and/or faster recovery from environmentally related or externally generated stresses
- developing strategies for better management of nutrient inputs and outputs across complex agricultural and natural resource systems, from field and farm to large watersheds
- harnessing spatial data and remote sensing technologies to map and model predictive simulations of environmental change

This framework represents the College's organizing outlook and leads to our critical issues.

### *Our critical issues and highlights from the 2020-2021 reporting year*

Our faculty's proficiencies span the gamut from molecular to global scale, from climate change to food and farm safety, from bioenergy to youth, families, and community development. Our research and extension programs help ensure that solutions to problems are economically viable, socially acceptable, and equitable.

In summer 2020, the College of Agricultural Sciences is expected to have a draft of our next College Strategic Plan that builds upon the accomplishments of the 2014–2019 strategic plan. A future plan of work will reflect the latest realignment of our critical issues with our new strategic plan. Consideration of the suitability of the critical issues outlined below, which are built upon previous planned programs, found them highly relevant to research and issues facing today's agriculture and communities.

This plan and the critical issues addressed will evolve with time as new challenges arise, issues evolve, and needs change. Below we highlight some of the noteworthy research and extension efforts from each critical issue this past year, *in addition to the key results featured.*

#### **Critical Issue: Advancing Agricultural and Food Systems**

Advancing Agricultural and Food Systems through the use of state-of-the-art technology and interdisciplinary collaboration to increase agricultural resiliency and efficiency.

- The Livestock Extension team offered a variety of programs to help beef, swine, meat goat, and lamb producers cut costs, maximize efficiency, and increase profits. They estimate the total increased income and economic benefit to participating producers across all programs at more than \$870,000.
- Citrus is one of the most important fruit crops, with an international gross production value of \$37.5 billion in 2016. Citrus breeding efforts, including for resistance against emergent diseases such as citrus greening, are hampered by the long period (6 years) before citrus trees normally reproduce. A Penn State/Florida team developed a new technique to reduce the generation time for citrus from 7 to 10 years to 1 to 2 years.
- Penn State researchers were part of an international team that discovered a plant hormone signal that causes roots to stop growing in compacted soils. This signal can be genetically inactivated to allow roots to push through hard soil. This discovery could help plants grow in even the most damaged soils.

An international team examined the substitution of organic fertilizer for chemical fertilizer among apple growers in China. The study suggested measures to improve farmers' income while implementing sustainable land management practices, and reducing the footprint of chemical fertilizers in apple production.

#### **Critical Issue: Building Community Resilience and Capacity**

*Building Community Resilience and Capacity* through integrated research and extension programming that promotes economic and social well-being by encouraging agritourism and entrepreneurship, community health, and sustainability in infrastructure, food, and energy systems.

- In a paper exploring housing market adaptation, a research team calculated that there are 8.1% more houses in Allegheny County, PA (Pittsburgh), due to flood insurance subsidies when premiums equal expected flood damage with subsidized flood insurance. If/when National Flood Insurance Program (NFIP) premiums rise by 50% to equal expected damages, property values will decrease by 8.8% in the short-term, with about half of that recovered in the long run. This analysis informs community planning and current NFIP revisions that strive to balance solvency and social consequences.

Extension programs in this area include:

- FarmSense, in which farmers learn about the financial statements involved in running a farm business. Participation in this program provided training that allowed at least 34 farmers to access more than \$2.5 million in borrowed funds for their businesses.
- Butcher School, which is designed to develop and promote the skills necessary to become a trained meat processor and to help relieve workforce shortages.

## Critical Issue: Developing Biologically Based Materials & Products

*Developing Biologically Based Materials and Products* to meet the promise of sustainable clean energy, beneficial reuse of agricultural waste, and income generation through new, value-added bioproducts to support struggling economies.

- Researchers considered the challenges, opportunities, and need for public policy reform in cellular agriculture—the synthesis of computer science, biopharma, tissue engineering, and food science to grow cultured meat, dairy, and egg products from cultured cells and/or genetically modified yeast.
- Another research team explored the producers, production, marketing, and sales of non-timber forest products (NTFPs) in the U.S., including the continuum of production from wild harvesting to forest farming of these products, and their costs and benefits. They identified information gaps, including the need for inventories and yield models of NTFPs, understanding the effect of silvicultural activities on NTFP survival and yield, time series and trends in collection of NTFPs by U.S. households, identification of vulnerable and marginalized communities associated with NTFP harvest, and harvesters' motivations and drivers.

*In addition to the highlighted projects below, we are highlighting the following:*

### **Biochar from agricultural waste products can adsorb contaminants in wastewater**

Biochar—a charcoal-like substance made primarily from agricultural waste products—holds promise for removing emerging contaminants such as pharmaceuticals from treated wastewater.

That's the conclusion of a team of researchers who conducted a novel study evaluating the ability of biochar derived from two common leftover agricultural materials—cotton gin waste and guayule bagasse—to adsorb three common pharmaceutical compounds from an aqueous solution. In this process, one material, such as a pharmaceutical compound, sticks to the surface of another, like the solid biochar particle.

Guayule, a shrub that grows in the arid Southwest, provided the waste for one of the biochars tested in the research. Guayule has been cultivated as a source of rubber and latex. The whole shrub is harvested, and its branches are mashed up to extract the latex. The dry, pulpy, fibrous residue that remains after stalks are crushed to extract the latex is called bagasse.

The results demonstrate the potential for biochar made from plentiful agricultural wastes that otherwise must be disposed of to serve as a low-cost additional treatment for reducing contaminants in treated wastewater used for irrigation.

Most sewage treatment plants are currently not equipped to remove emerging contaminants such as pharmaceuticals, and if those toxic compounds can be removed using biochars, then wastewater can be recycled in irrigation systems. That beneficial reuse is critical in regions such as the U.S. Southwest, where a lack of water hinders crop production.

The pharmaceutical compounds used in the study to test whether the biochars would adsorb them from aqueous solution included sulfapyridine, an antibiotic no longer prescribed for treatment of infections in humans but commonly used in veterinary medicine; docusate, widely used as a laxative and stool softener; and erythromycin, an antibiotic used to treat infections and acne.

The results suggest that biochars made from both of these agricultural waste materials could act as effective adsorbents to remove pharmaceuticals from reclaimed water prior to irrigation. The biochar derived from cotton gin waste was much more efficient, adsorbing 98% of the docusate, 74% of the erythromycin, and 70% of the sulfapyridine in aqueous solution. By comparison, the biochar derived from guayule bagasse adsorbed 50% of the docusate, 50% of the erythromycin, and just 5% of the sulfapyridine.

The research revealed that a temperature increase from about 650 to about 1,300 degrees F in the oxygen-free pyrolysis process used to convert the agricultural waste materials to biochars, resulted in a greatly enhanced capacity to adsorb the pharmaceutical compounds.

There have been no previous studies on the use of guayule bagasse to produce biochar for the removal of emerging contaminants. This is the first study to use cotton gin waste specifically to remove pharmaceuticals from water. Because cotton gin waste is widely available, even in the poorest regions, it holds promise as a source of biochar to decontaminate water.

The [research](#) was published in the journal *Biochar*.

### **Critical Issue: Fostering a Positive Future for Youth, Families, & Communities**

*Fostering a Positive Future for Youth, Families, and Communities* by providing a wide range of evidence-based programming to support healthy families, build positive youth skills, strengthen intergenerational relationships within communities, and promote farm safety.

- A study analyzed the perceptions of Latinx immigrant mushroom workers' on how the workplace environment shapes occupational safety and health and examined whether and how those perceptions differ by gender. Additionally, future areas for research on occupational safety and health in the mushroom industry were identified. Approximately one-third of respondents had suffered an injury at work, and nearly half felt that workplace factors affect their health and safety. The study found that Latinx mushroom farmworkers recognized risks posed by the indoor infrastructure of mushroom production houses and by the organization of mushroom production work.

**Critical Issue: Promoting Environmental Resilience**

*Promoting Environmental Resilience* by assessing and protecting ecosystems and ecosystem services, helping agriculture meet its environmental challenges, promoting ecosystem resilience and health, and mitigation and adaptation to climate change.

- Penn State green industry faculty worked with staff of Penn State's Agricultural Analytical Services Lab to interpret and support green roof soil sample analysis. This program is widely used by the green roof industry in North America. Interpretation and support for nutrient management on green roofs improves plant performance and sustainability, helps ensure optimum performance of campus green roofs, and reduces the environmental impact of runoff from green roofs.
- Members of the Forestry and Wildlife Extension team developed a unique impact-measuring tool and illustrated how Extension professionals can use it to understand how much value their program adds to a leader's decision-making process in natural resources. The findings indicated that research-based information transfer strategies might increase the perceived value of Extension programs when they are successful at helping natural resources leaders make more practical and objective judgments in their decision-making process.

**Critical Issue: Supporting Integrated Health Solutions**

*Supporting Integrated Health Solutions* by developing functional foods for positive health outcomes, overcoming food safety concerns, fostering human and livestock health, and fighting insect-borne diseases and parasites.

- Since 2009, Pennsylvania has had more Lyme disease cases than any other state. Penn State Extension's transdisciplinary Vector-Borne Disease (VBD) Team uses the "One Health" framework to deliver education on VBDs to specific at-risk groups. The team produced an educator toolbox, including standard VBD-related slide decks and presentation materials as well as a train-the-trainer workshop, to prepare other extension educators to address the VBD concerns of their stakeholders.
- A study found that supplementation of cocoa powder in the diet of high-fat-fed mice with liver disease markedly reduced the severity of their condition. The researchers suggested that the results have implications for people. By waiting until mice were already obese before beginning cocoa treatment, researchers were able to test the protective effects of cocoa in a model that better simulates the current public health situation related to non-alcohol-related fatty liver disease. That's important because a significant proportion of the world's population has preexisting obesity and non-alcohol-related fatty liver disease, so there is a need to develop potentially effective dietary interventions rather than just preventive agents.
- The Food Safety Modernization Act (FSMA) Extension team targeted underserved audiences of Amish produce growers and Spanish-speaking growers and processors with various education opportunities on the Produce Safety Rule and the Preventive Controls Rule in FSMA.

**Merit and Scientific Peer Review Processes**

---

**Updates**

For the most part, the Merit Review Process submitted for the FY2021-2025 Plan of Work remains accurate with the following update:

Combined internal and external university panels are assigned to each of the programmatic issues. These panels are integrated, multidisciplinary State Program Teams made up of field-based extension educators and faculty with split appointments in both extension and research. Team members broadly represent all parts of the Commonwealth, and faculty members are chosen to represent relevant research and extension perspectives. Extension Program Leaders provide overall leadership to the State Program Teams, and programs are reviewed by extension administrators. State administrators and academic unit leaders serve as liaisons to each team. Each State Program Team developed a program plan, based on logic model components, that will guide extension programming and applied research efforts.

## Stakeholder Input

---

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

College administration and faculty advisory groups will confer regularly with key stakeholder groups, state and federal partners, and relevant industry representatives across the breadth of interests in the College. Listening sessions, targeted invitations, surveys, focus group meetings, and engagement on social media will all seek input from traditional and nontraditional stakeholder groups and/or individuals. A primary avenue for stakeholder input is via the various forms of feedback obtained in connection with extension offerings, from volunteered comments and formally sought assessments of learning and effectiveness to retrospective evaluations that seek to measure outcomes such as costs averted or profit increased from implementing extension program suggestions. All of these forms of feedback will be taken together to help set the course for PSE and AES programs. The results of these assessments will be incorporated into our Extension Program SharePoint site.

### Methods to identify individuals and groups and brief explanation

The Methods to Identify Individuals and Groups submitted for the FY2021-2025 Plan of Work remains accurate and up-to-date.

### Methods for collecting stakeholder input and brief explanation

The Methods for Collecting Stakeholder Input submitted for the FY2021-2025 Plan of Work remains accurate and up-to-date.

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

The Statement on How Input will be Considered for the FY2021-2025 Plan of Work remains accurate and up-to-date.

## Highlighted Results by Project or Program

---

Critical Issue

### Advancing Agricultural and Food Systems

---

#### **Agronomy Programming**

Project Director

Chris Houser

Organization

Penn State University Park

Accession Number

7001753



#### **Penn State Extension Agronomy Programming**

---

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

**Issue: Sustainable field and forage crop production and emerging crop markets**

The 2020 USDA Census of Agriculture estimated field and forage crop production value at \$2 billion in Pennsylvania. A 20% increase in corn and 40% increase in soybean exports shows the need for continued growth and efficiency in crop production (USDA FAS, 2020). Production of forage crops has large room for growth. Despite being the largest crop in Pennsylvania with a reported 1.62 million acres harvested at an estimated value of just over \$880 million, according to the 2020 USDA State Agriculture Overview, forage yield increases are minimal. NASS QuickStats Surveys states that the 5-year Pennsylvania corn average yield in bushels per acre has increased 12% in 9 years, while hay and haylage yield over the same 9-year period have only increased 5% across the state. There is additional demand regionally for hullless barley, non-GMO soybeans and organic field crops. Hemp production, though demand is low, farmers seek educational resources to become versed and proven in this new crop as the market develops. The public, landowners and growers continue to require crop systems remain sustainable. Profitability, social and economic equity and environmental stewardship continue to influence decisions of, for and with farmers. Soil health, agricultural awareness, nutrient management, and pest management have become key topics to both farmer and public as we navigate changing beliefs and regulations.

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

This winter our Field & Forage Crops Team moved quickly in conjunction with Pesticide Education to continue support for pesticide meetings in unique ways despite travel and meeting restrictions. Our teams recorded fifteen 30–40-minute video presentations worth pesticide core and category recertification credits saved to flash drives. These presentations were broadcast at 29 events and provided approximately 5,000 applicator credits to 1,648 individuals and trained another 120 unlicensed applicators and professionals.

An in-person training course for participants to learn about pesticide safety and prepare for the Pennsylvania private applicator licensing exam was transitioned to a virtual format. Seventy-three people participated in the course. After the course, a random sample of participants were surveyed – all those surveyed passed their licensing exam. Most survey respondents indicated that their knowledge significantly increased in pesticide safety, proper pesticide transport and storage, and integrated pest management tactics.

To provide unbiased, science-based recommendations to the grain crop industry, the team conducted a broad range of extension activities in Pennsylvania, including 92 local grain crops extension events that attracted several hundred participants. These farmers collectively manage more than 172,000 acres of grain crops. Our team also used a range of indirect methods to create awareness about management tactics, inform about new varieties and share recommendations regarding other crop production, storage, and marketing challenges. These included over 40 articles in our weekly e-newsletter, the Penn State Field Crop News.

We collaborated with the PA Soybean Board to conduct 51 research trials during 2021 with support from funds generated by the PA Soy Check-off program.

One key positive factor has been an increasing acreage rotated to soybeans as a result of the Soybean Workshops, Soybean Congress, and the Soybean On-Farm Network reaching out to growers in Northern Pennsylvania. Acreages of soybean grown in some of these counties have doubled or tripled compared to those grown just three or 4 years ago. Furthermore, soybean yields in some of these areas' yields are approaching 75 bu/acre, which are very high for the shorter season varieties required in these regions due to shorter growing season. The team continues to receive growing interest from growers for our small grain and soybean testing and this has led to more entries each year and motivated us to continue to expand the program. Our team has adopted more regional approaches to programming, has developed more workshops that are offered across the state, has developed more webinar-based delivery options, continues to develop significant funding to supplement extension funding, and has built relationships with numerous related support and industry groups (PA Conservation Districts, PA Soybean Board, Professional Dairy Managers of Pa, PA No-till Alliance, NRCS, seed industry and equipment industry representatives).

Attendance at the 2021 Farming for Success Field Day was just over 250 with about equal thirds, farmers, private industry reps, and other agricultural professionals in attendance. The field day, held at the Penn State Southeast Research and Extension Center, Manheim, PA offers a wide range of production ag topics, demonstrations and presentations. In 2021, a total of 15 topics were available to choose. Survey results pending.

In 2021, the team addressed soil fertility and sampling, improved livestock grazing practices, and improved stored forages. Forages are the top produced crop in Pennsylvania with a reported 1.62 million acres harvested at an estimated value of just over 880 million dollars, according to the 2020 USDA State Agriculture Overview. Furthermore, NASS QuickStats Surveys state that the 5-year Pennsylvania corn average yield in bushels per acre has increased 12% in 9 years, while hay and haylage yield over the same 9-year period, yields have only increased 5% across the state. To address these issues, the team held a 5-part web series that focused on improving forage management and production. This event was attended by 255 participants from 26 states and three other countries. Participants were producers, industry, and government representatives. This series was recorded and had 316 views.

In addition to specific OREI project activities, the team developed 7 peer reviewed articles, 9 Penn State Extension articles, 1 Extension video, 1 Organic Crop Production Guide and 11 presentations to farmer-based audiences (mainly virtual). In winter, Penn State sponsored and hosted a series of webinars (with the Rodale Institute, Northeast SARE, and the PA Dept of Agriculture) focused on reduced tillage organic systems with 250-300 attendees at each session. Two Penn State members led a presentation one day of the series with 235 attendees. Other virtual farmer-focused meetings included a Soil Ecology and Soil Health five-part webinar series with 478 registrants; attendees ranged in number from 127-280 per session. Two members also presented aspects of organic soil carbon and pest management at a Virtual Crops Conference with 54 attendees. Members also participated in an Organic Field Equipment Day led by regional partners with 200 attendees: 150 farmers, and 50 other ag service providers. Team members are contributing expertise and resources to the Organic Trade Association's Organic Agronomy Training Service to educate service providers about organic agriculture in bi-monthly meetings. Overall outreach was to approximately 1170 farmers (905) and organic ag service providers and community members (267).

The "Industrial Hemp Webinar Series" and "Hype about Hemp" online programs allowed attendees to tune into research-based updates on hemp production, processing, and marketing – 681 participants in total.

Soil health management affects crop productivity, soil erosion, nutrient losses, biological activity and carbon sequestration. The team provided a multi-dimensional extension program, particularly on stimulating farmers to use cover crops more

consistently. Our team produced 20 articles produced in Field Crop News (>10,000 subscribers), which often get published by national farm press too. Five Cover Crops Pay Webinars focusing on different aspects of cover crops attracted 274 registrants, representing up to 500,000 acres of cropland per session. A 5-part dairy double cropping webinar series had 120 registrants representing 273,000 acres of cropland. Despite COVID-19, our team was able to provide field workshops. Four on-farm field days on grazing cover crops for soil health were given and multiple demonstrations at Ag Progress Days to a total of more than 200 attendees. A no-till vegetable demonstration at Ag Progress Days attracted 43 attendees. Demonstrations of 33 different cover crop species and mixes at two different venues attracted 110 attendees. A soil compaction demonstration at Farming for Success in Landisville attracted 100 attendees. Team members gave 3 guest lectures to university students at Penn State and New Mexico State, gave a webinar to the World Congress of Conservation Agriculture, No-Till Farmers (U.S. farm organization), audiences in Ohio and New York, and in Pennsylvania for a total of more than 4000 attendees. Annual cover crop surveys held from 2016-2021 in the Chesapeake Bay watershed of Pennsylvania by an independent agency (Capital RC&D Council). Showed that cover crop adoption is on average 39%, or 590,000 acres annually in Pennsylvania. Even a modest \$10 per acre worth of reductions in sediment and nutrient losses to surface waters would be almost \$6 million per year. Most notable is the high 39% adoption of cover crops in the Chesapeake Bay watershed of Pennsylvania. This far exceeds that in the Midwest, where cover crop adoption is less than 10%. This is the result of many years of education but nonetheless shows the impact we are having as leaders in cover crop adoption techniques and best practices.

Maintaining water quality while balancing the efficient and profitable operations of crop and livestock producers is a key issue that the soil fertility and nutrient management sub-team focuses on. In the 2020-21 program year, 1,301 Pennsylvania farms had Nutrient Management Plans approved for their operations using planning tools and nutrient recommendations developed by Penn State Extension. These approved operations have a net total of 261,525 cropland acres under plan. There are about 800 individuals certified in the Pa Commercial Manure Hauler and Broker Program that service an average of 38.5 farms annually, so education for this audience has amplifying impact.

The Penn State Agricultural Analytical Services Lab (AASL) provides analytical testing and research-based recommendations to support resource management decisions. The AASL is one of the premier state soil testing labs in the country, offering a wide range of services including soil testing, plant tissue analysis, and manure analysis. In fiscal year 2021, the AASL fulfilled 50,000 soil fertility tests, 6,500 plant tissue tests, 2000 manure, compost, and biosolids tests. These analytical services are a critical tool that empowers farmers and agronomists to make economically viable and environmentally sound decisions about nutrient application rates to cropland.

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

Pesticide education was also offered in a virtual format with three webinars. Over 1,100 applicators participated in the webinars. Of those surveyed, 80% indicated that they were farmers with 123,000 acres in production. Most participants (88%) indicated that the program would have a positive cash impact on their business and 93% reported that their knowledge about pesticide safety and pests had increased. Participants resided in 62 out of the 67 counties in Pennsylvania.

An in-person training course for participants to learn about pesticide safety and prepare for the Pennsylvania private applicator licensing exam was transitioned to a virtual format. Seventy-three people participated in the course. After the course, a random sample of participants were surveyed – all those surveyed passed their licensing exam. Most survey respondents indicated that their knowledge significantly increased in pesticide safety, proper pesticide transport and storage, and integrated pest management tactics.

Three crop workshops held across PA during December 2020-2021 resulted in participation of 93 farmers. A formal evaluation of this group resulted in survey responses from 80 percent of the group. The amount of acreage present at the meetings was quite impressive. Nearly 31% of farmers had over 500 acres, 44% of farmers have acreage between 51 and 200 acres. There were 18,050 acres or more represented at the workshops. 73% indicated that they were going to adopt two practices in the near future, and 69% were likely to apply new practices to their operations this season. Notable producer comments included “Excellent program”, “So much to cover, make it a longer day”, “These workshops are a great idea”, “Very well put together, lots of useful information”, “Gave me a couple of good ideas and some new techniques to work with” and “Very practical topics and discussions”

The forage management web series produced the following survey results measuring the before and after knowledge of the participants. Of the 129 surveyed participants, 70% indicated they will adopt one of more new practices. Of the 27 participants who answered the question “Do you feel attending the program will have a positive cash impact on your business?” Twenty-four, or 89%, answered yes. Based on participant answers to the question “How many acres do you farm/serve,” this is a positive economic impact on approximately 20,400 acres.

Of 191 attendees at the “Evaluation of CBD: Research Update”, 20 respondents reported the following: 55% indicated that their knowledge of industrial hemp production practices and variety selection significantly increased. 45% indicated that their knowledge of industrial hemp production practices and variety selection moderately increased. 0% indicated that they did not increase their knowledge. 30% indicated that they will change practices related to CBD production and/or variety

selection as a result of attending this webinar. 20% indicated that they are considering changing practices related to CBD production and/or variety selection as a result of attending this webinar.

Of attendees viewing a "Cover Crops Pay" webinar series, 65-70% reported increase in knowledge about cover crop practices presented, and 36-37% planned to adjust nitrogen rates or use planting green in their cover crops.

A 5-part dairy double cropping webinar series had 120 registrants representing 273,000 acres of cropland. 53-89% reported increase in knowledge on forage quality, ensilage, and feeding of small grain silage, and up to 55% reported the information would have a positive effect on their cash balance.

As a result of the cover crop and soil health programs, one producer purchased a no-till drill and is planning to actively transition 120+ acres to no-till production; one producer planted green into a small grain cover crop on approximately 20 test acres; two producers plan to use additional cover crop species to help alleviate compaction issues; another producer is expanding his grazing operation.

As a result of the Nutrient Management and Soil Fertility Discussion Hours, over 100 hours of recertification credits were earned by attendees to maintain licenses for Nutrient Management Planning and Manure Hauling in Pennsylvania.

Participants were very active in discussion, submitting 18 questions during just one session of the event. Attendees agreed the program time was well spent commenting, "Thanks much! Great information." and "is this [meeting] being recorded so we can listen to it again?"

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

On an online survey sent to both industry members and crop/livestock farmers, Penn State Extension was rated as the most commonly used source for keeping informed about field and forage crops information (89% of respondents used Penn State Extension). A respondent specifically stated on the survey, "Thank you for all your programs. Your support has been amazing!" The team also recently held five stakeholder interviews with various members from farming industries, government agencies, and with farmers to gain further insight into how the Field and Forage Crops team can better meet the educational needs of their audiences. One stakeholder commented during the conversation that, "[The team is] already doing a huge amount [of online training]. My email loads up every morning with about 6 or 8 of it...that's a great job there." Various stakeholders commented that they think highly of various products that the team offers, as one stakeholder commented that they "think [the Agronomy Guide is] a wonderful resource." Similarly, another stakeholder commented that they are, "thankful for the publications that [the team does]." Another stakeholder commented during the interviews held that, "I loved [the team's] outdoor movie theater [drive-ins]...That was ingenious."

### **Impact Statement (Optional)**

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

### **Grower adoption of cover crops yields at least \$6 million in ecosystem services yearly**

Annual cover crop surveys conducted from 2016 to 2021 in the Chesapeake Bay watershed of Pennsylvania by an independent agency (Capital RC&D Council) showed that cover crop adoption is on average 39%, or 590,000 acres annually in the Chesapeake Bay watershed of Pennsylvania.

Planting and growing a strategic mix of cover crops reduces the loss of nitrogen from farm fields, protecting water quality in the Chesapeake Bay. The practice can also contribute nitrogen to subsequent cash crops, improving yields.

Cover crops provide additional benefits associated with living cover and roots, such as weed suppression; beneficial insect habitat; increased soil organic matter, biological activity and structure; and nitrogen sequestration (non-legumes).

Even a modest \$10 per acre worth of reductions in sediment and nutrient losses to surface waters would amount to almost \$6 million per year.

The Soil Health and Nutrient Management sub-teams, including faculty in the Departments of Plant Science and Ecosystem Science and Management, have for several years been researching cover crops best practices and educating farmers about their findings. All cover crop-related research has an outreach component. For instance, the team has studied "planting green" and maximizing corn emergence, and the effect of planting green on suppression of herbicide-resistant weeds. Planting green is the practice of planting cash crops into living cover crops instead of the more common practice of planting into desiccated cover crops previously killed with an herbicide. Among other practices, they've also studied broadcasting cover crop seed into standing soybeans to broaden the window for establishment, and drill-interseeding into growing corn.

The team presents research results at crop days, winter meetings, field days, Ag Progress Days, and industry events; in online newsletters such as Field Crop News; and in press releases, webinars, and other venues.

The rate of cover crop adoption in Pennsylvania far exceeds use of the practice in the Midwest, where cover crop adoption is less than 10%. This is the result of many years of education and shows the impact Penn State Extension and its partner, the Pennsylvania No-Till Alliance, are having as leaders in cover crop adoption techniques and best practices. Cover cropping is more important in Pennsylvania's hilly topography, where nutrient runoff and erosion present greater challenges than in the Midwest.

Maintaining water quality while balancing the efficient and profitable operations of crop and livestock producers is a key focus of the Soil Health and Nutrient Management sub-teams.

## [Developing management strategies for button mushroom cultivation to manage diseases and improve yield and to optimize cultivation practices for specialty mushrooms](#)

Project Director

John Pecchia

Organization

Penn State University Park

Accession Number

1023198



### **Management Strategies for Button Mushroom Cultivation to Manage Disease and Improve Yield**

---

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

Applied production projects include research on disease management and alternative materials, particularly peat moss substitution/supplementation during 2021-2022. Labor challenges are being addressed focusing on both harvesting and packaging of *Agaricus* mushrooms. Research is also focusing on production of specialty mushrooms such as morel, oyster and nameko mushrooms, and the role that the compost and casing microbiome plays on mushroom formation and disease development.

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

*Agaricus* cropping experiments during 2021 focused on looking for peat moss substitutes to address the supply shortage facing the industry. Strain screening for nameko and oyster mushrooms led to the selection of a strain of each that is best suited to grown in cooler climates. Based on mating type determination, isolates were chosen for ongoing indoor and outdoor cropping experiments. A large USDS SCRI grant was obtained to further our work on improving harvesting speed and automation on *Agaricus* mushroom farms.

Results from casing alternative experiments have identified 2 possible peat alternatives that are now being used to supplement sphagnum peat moss for use as casing by some commercial growers. An increased understanding of the role that mating type and species selection plays on morel cultivation will increase the chances of success for commercial production moving forward.

Results from the microbiome work will take further investigation into the basic science of the biology of the substrate to develop systems to improve disease resistance and improve mushroom yield. This component of our project if a moderate to long-term commitment to improve cropping biological efficiencies.

Results from casing alternative experiments have identified 2 possible peat alternatives that are now being used to supplement sphagnum peat moss for use as casing by some commercial growers. An increased understanding of the role that mating type and species selection plays on morel cultivation will increase the chances of success for commercial production moving forward.

Results from the microbiome work will take further investigation into the basic science of the biology of the substrate to develop systems to improve disease resistance and improve mushroom yield. This component of our project if a moderate to long-term commitment to improve cropping biological efficiencies.

Results from casing alternative experiments have identified 2 possible peat alternatives that are now being used to supplement sphagnum peat moss for use as casing by some commercial growers. An increased understanding of the role that mating type and species selection plays on morel cultivation will increase the chances of success for commercial production

moving forward.

Results from the microbiome work will take further investigation into the basic science of the biology of the substrate to develop systems to improve disease resistance and improve mushroom yield. This component of our project is a moderate to long-term commitment to improve cropping biological efficiencies.

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

Results from casing alternative experiments have identified 2 possible peat alternatives that are now being used to supplement sphagnum peat moss for use as casing by some commercial growers. An increased understanding of the role that mating type and species selection plays on morel cultivation will increase the chances of success for commercial production moving forward.

Results from the microbiome work will take further investigation into the basic science of the biology of the substrate to develop systems to improve disease resistance and improve mushroom yield. This component of our project is a moderate to long-term commitment to improve cropping biological efficiencies.

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

The broader public in Pennsylvania benefited from our alternative casing experiments by allowing mushroom growers to survive a serious threat to the survival of the mushroom industry that is not able to survive without a viable casing product (which has historically been 100% Canadian supplied peat moss). The economic impact of the Pa mushroom industry reaches far beyond the property lines of the farms themselves.

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

Publication Results:

- Vieira, F and Pecchia, J. 2021. Bacterial community patterns in the *Agaricus bisporus* cultivation system, from compost raw materials to mushroom caps. *Microbial Ecology*. <https://doi.org/10.1007/s00248-021-01833-5>
- Vieira, F and Pecchia, J. 2021. Fungal community assembly during high-temperature composting under different pasteurization regimes used to elaborate *Agaricus bisporus* substrate. *Fungal Biology* 125(10):826-833.
- Harvey, R.J., D.D. Davis, B. Savini, R. Brennan, and J.A. Pecchia. 2021. Nitrate removal in greenhouse wastewater using mushroom compost within artificial wetlands. *J. Plant Sci. & Res.* 8:pp, [www.opensciencepublications.com](http://www.opensciencepublications.com) .8(2):210-214.
- Huang, M., He, L., Choi, D., Pecchia, J. and Li, Y. 2021. Picking dynamic analysis for robotic harvesting of *Agaricus bisporus* mushrooms. *Computers and Electronics in Agriculture*, 185,106145.
- Huang, M., Jiang, X., He, L., Choi, D., **Pecchia, J.**, and Li, Y. 2021. Development of a robotic harvesting mechanism for button mushrooms. *Transactions of the ASABE*. 64(2):565-575.

### **Impact Statement (Optional)**

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

**Researchers develop prototype of robotic device to pick, trim button mushrooms**

Researchers have developed a robotic mechanism for mushroom picking and trimming and demonstrated its effectiveness for the automated harvesting of button mushrooms. The prototype, which is designed to be integrated with a machine vision system, is capable of picking and trimming mushrooms growing in a shelf system.

This development is important because the mushroom industry has been facing labor shortages and rising labor costs. Mechanical or robotic picking can help alleviate those problems.

The mushroom industry in Pennsylvania produces about two-thirds of the mushrooms grown nationwide. A total of 891 million pounds of mushrooms valued at \$1.13 billion were consumed in the U.S. from 2017 to 2018. Of this production, 91% were for the fresh market, according to the U.S. Department of Agriculture, and were picked by hand, one by one, to ensure product quality, shelf life, and appearance. Labor costs for mushroom harvesting account for 15–30% of the production value.

The robotic mushroom-picking mechanism includes a picking device, a system to move the picking device, a mushroom stem-trimming device, and an electro-pneumatic control system. The laboratory-scale prototype validates the performance of the mechanism.

The prototype is described in an [article](#) recently published in *Transactions of the American Society of Agricultural and Biological Engineers*. Results showed that the picking end-effector was successfully positioned to the target locations and its success rate was 90% at first pick, increasing to 94.2% after second pick.

The device uses a suction cup mechanism to latch onto mushrooms, so the team conducted bruise tests on the mushroom caps to analyze the influence of air pressure and acting time of the suction cup. The bruise tests indicated that the air pressure was the main factor affecting the bruise level, compared to the suction-cup acting time. An optimized suction cup may help to alleviate the bruise damage.

The trimming mechanism achieved a success rate of 97% overall. Laboratory test results indicated that the developed picking mechanism has potential to be implemented in automatic mushroom harvesting.

The work integrates with other research and extension efforts to advance the mushroom industry in Pennsylvania and the United States.

Closing Out (end date 09/07/2023)

## [Improvement of athletic field playability and athlete safety through manipulation of soil physical properties, cultural practices, and turfgrass morphology](#)

Project Director

Andrew McNitt

Organization

Penn State University Park

Accession Number

1023291

### **Improvement of athletic field playability and athlete safety through manipulation of soil physical properties, cultural practices, and turfgrass morphology Results 2021**

---

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

Approximately 3.5 million children under age 14 are hurt annually competing in sports. These injuries cost the US public over 49 billion dollars. Numerous epidemiological studies indicate that the condition of the playing surface is a critical risk factor contributing to sports related injuries. This project attempts to improve the safety and playability of natural and synthetic turf systems commonly used by all level of athletes from youth sports to the professional level. The results should help school and park officials make sound decisions when considering the construction and maintenance of sports fields.

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

A field testing protocol was developed by experts in sports turf biomechanics, medical doctors, athletic trainers, and sports turf managers. This testing protocol was made mandatory in the NFL and every game field had to pass the protocol before each game. A description of the protocol was published: Jastifer, J. R., McNitt, A. S., Mack, C. D., Kent, R. W., McCullough, K. A.,

Coughlin, M. J., Anderson, R. B. 2021. The development of mandatory practices for the testing and maintenance of synthetic turf fields in the National Football League. *Int Turfgrass Soc Res J*; 1–12. <https://doi.org/10.1002/its2.94>

A device and testing protocol has been developed for the improvement of the non turf basepath surface used in baseball. This newly developed protocol has been communicated to the scientific community, those with business interests in this area, and sports field managers. Examples:

Mascitti, E., A.S. McNitt. 2021. A new laboratory method for measuring surface disruption of baseball infield soils. *ASA, CSSA and SSSA Annual Meetings (Salt Lake City, UT)*. November 9.

Mascitti E., A.S. McNitt. 2021. Safe Baseball Infields. Cornell Turfgrass Show Episode 10. Podcast. April 9.

Mascitti, E., A.S. McNitt. 2021. What Makes a Quality Infield Mix. Fresh Cut Grass Podcast, Penn State Extension, Season 1, Episode 9. May 14.

This methodology is being used to evaluate new soil types in an attempt to improve the safety and playability of baseball surfaces.

This project continues to investigate the relationship of surface and athlete in regards to traction and lower extremity injuries. A paper was published this year. Kent, R., Yoder, J., O’Cain, C. M., Meade Spratley, E., Arbogast, K. B., Sorochan, J., McNitt, A.S., Serensits, T. 2021. Force-limiting and the mechanical response of natural turfgrass used in the National Football League: A step toward the elimination of differential lower limb injury risk on synthetic turf. *Journal of Biomechanics*, 127. <https://doi.org/10.1016/j.jbiomech.2021.110670>

A paper was published on research regarding MRSA survival and various methods used to reduce the presence of MRSA on turf systems. McNitt, A.S., D.M. Petrunak, and T.J. Serensits. (2020). Survival of *Staphylococcus aureus* applied to *Poa pratensis*, L. and Synthetic Turf. *Int. Turf. Soc. Res. J.* 12:1053-1065. [doi.org/10.1002/its2.35](https://doi.org/10.1002/its2.35)

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

The field testing protocol has been reviewed by other professional and collegiate sports leagues as well as high school and park and recreation professionals. Many have begun to implement similar programs using this report as a model. This should raise awareness as to how daily maintenance procedures affect parameters related to athlete injury.

The new methodology related to baseball infield soil evaluation has been presented to various audiences. Currently this protocol is of has drawn the most attention from commercial firms operating in this discipline. They see the potential to improve their products. As more experiments are completed, those managing sports fields will take greater notice as the results can be applied as improvements of playing conditions can be realized.

Both shoe and turf manufacturers have been reviewing the research presented as it informs their decisions on how to improve their products and reduce injuries. Other target audiences include sports field managers, coaches, trainers, youth athlete parents etc. Easily digested information regarding selection of shoe types has been developed and distributed to aid in athletic shoe selection for various surface types.

The information on bacteria survival on turf surfaces was directed at Methicillin Resistant *Staphylococcus aureus* but had some relevancy for treatment of playing surfaces for Covid 19.

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

Improvements in athletic surfaces and footwear, benefits the public benefits via reduced injury rates. Higher quality and safer surfaces should help to increase participation in athletic activities and increase general health.

### **Impact Statement (Optional)**

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

### **Survival of *Staphylococcus aureus* applied to Kentucky bluegrass and synthetic turf**

*Staphylococcus aureus* is a common bacterium found on human skin and in the nose. Typically, the presence of the bacterium causes no problems and goes unnoticed. Occasionally, *S. aureus* is capable of causing diseases ranging from minor soft tissue infections and food poisoning to serious medical problems such as toxic shock syndrome. Most community-associated *S.*

*aureus* infections are believed to be transmitted either via person-to-person contact or through a common source or shared items.

Strains of *S. aureus* demonstrating resistance to  $\beta$ -lactam antibiotics were first noted in the 1960s and are termed methicillin-resistant *Staphylococcus aureus* (MRSA). MRSA isolates have become more prevalent among athletes. The role of surfaces in the locker rooms, training rooms, and sports fields with which these players interact has been questioned as potential sources for transmission of *S. aureus*.

Penn State researchers studied the survival of *S. aureus* on synthetic turf systems and natural turfgrass under varying environmental conditions and to evaluate the effectiveness of various control agents applied to the synthetic turf.

Under non-extreme temperature and very limited light conditions, less than 4% of the *S. aureus* applied survived on both synthetic and natural turfgrass for 12 days. Applied control agents reduced survival rates to less than 1% survival at 6 days for all but one treatment. When *S. aureus* was applied to outdoor surfaces in the presence of sunlight, the bacterial survival rate was reduced to under 1% survivability within 2 hours of *S. aureus* application on synthetic turf and within 3 hours on natural turfgrass. Exposure to UV light and higher temperature seemed to be an effective disinfectant under the conditions of this experiment. Survival rates on synthetic and natural turfgrass did not differ greatly in indoor conditions.

The [article](#) was published in the *International Turfgrass Society Research Journal*.

### **Improving Vegetable Production Systems Sustainability and Vegetable Quality**

Project Director

Francesco Di Gioia

Organization

Penn State University Park

Accession Number

1020664



### **Improving Vegetable Production Systems Sustainability and Vegetable Quality: 2021 results**

---

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

The present project addresses issues associated with the sustainability of current vegetable production systems and the quality of vegetable products.

The project aims to assist the PA Vegetable Industry in generating science-based knowledge and solutions to support vegetable growers in the adoption of new production systems, the introduction of new crops, technical innovations, and more efficient agronomic practices, which in turn will contribute to improving the long-term sustainability of PA vegetable production systems.

Health-conscious consumers increasingly demand high-quality, locally and sustainably produced fresh vegetable products. This project is aimed to develop and transfer science-based solutions to assist growers in responding to the consumers' demands, enabling growers in: i) managing soilborne pests and pathogens minimizing the use of synthetic chemistry; ii) improving the use efficiency of resources such as water and fertilizer; iii) enhancing crop response to abiotic stress conditions; iv) enhancing the quality and nutritional profile of vegetable products.

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

In 2021 a series of integrated research and extension activities allowed significant progress toward each of the goals defined for this project:

1) In relation to the first objective (Evaluate anaerobic soil disinfestation as an alternative to chemical soil fumigation in Pennsylvania vegetable growing systems), we have examined the potential in developing anaerobic conditions of different alternative by-products of the agrifood industry as carbon sources for the application of anaerobic soil disinfestation, examining their impact also on crops and nutrient dynamics. This work allowed us to identify the most promising carbon sources that will be used for further research and extension work.

2) In relation to the second objective (Evaluate monitoring tools, sensors, and smart technologies for the efficient irrigation and nutrient management of vegetable crops), our work focused on the high tunnel and controlled environment production systems. For high tunnels, we have examined the response of grafted and non-grafted tomato plants to nitrogen inputs while assessing the efficacy of two different in-season soil monitoring methods, in combination with two different portable sensors for the on-farm analysis of nitrates in soil water extracts. The study revealed the importance of conducting the in-season monitoring of nitrate levels in the soil to prevent excessive applications of nitrogen fertilizer that may lead to an excess of salinity and reduced soil health and crop productivity. The study revealed the efficacy of the in-season soil monitoring tools with relative advantages and disadvantages and their limitations. The study revealed that the reliability of the ion-selective electrodes tested is influenced by the pH of the solution analyzed. Both types of sensors, provide good results when the pH ranges between 6 and 7, and are subject to interferences especially when the pH is above 7. These results suggest more research is needed in order to propose this method for soil characterized by  $\text{pH} > 7$ . The same study also revealed the potential of using grafted plants to enhance plant vigor and crop yield, and more data analysis is ongoing to evaluate how grafting influenced the uptake of nitrogen and other minerals compared to non-grafted plants in a high tunnel production system.

In a controlled environment, we have tested the efficacy of an automated sensor-based irrigation system in rationalizing the irrigation of basil grown in pots in a peat and perlite mix, thereby increasing water and nutrient use efficiency while increasing yield and product quality. The use of an automated sensor-based irrigation system while requiring some improvements may allow remote control of the crop reducing the need for specialized human resources for the management of the crop.

3) In relation to the third objective (Evaluate yield and quality response of vegetable crops to alternative agronomic practices and to abiotic stressors and agronomic vegetable biofortification) we have conducted a series of experiments to evaluate the opportunity of using supplementary zinc fertilizer solutions and seed priming techniques to enhance the content of zinc in pea shoot microgreens. The results of the research suggest that it is possible to increase zinc content without reducing crop yield, but not all the sources of zinc fertilizer are effective. Moreover, the increase in zinc resulted in a slight decrease in iron content. Based on these results more research is needed to identify other effective agronomic biofortification strategies for enhancing zinc and iron content simultaneously. For the same project objective, we have conducted experiments aimed at evaluating the effect of ultraviolet (UV) radiation on the yield and quality components of microgreens. These studies revealed the potentially detrimental effect of UV-B radiation when exposing the plant to high UV-B radiation intensity for a period of time above 3 hours per day. More research is needed to evaluate the potential effect of UV-A and UV-B radiation on the yield and quality of microgreens for exposure periods below one hour per day.

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

The target audience of this project is represented by vegetable growers operating in Pennsylvania and in the US. The group includes both beginning and more experienced growers, growers belonging to Plain Sect Communities, and growers of Hispanic origin. Other target audiences served by this project are undergraduate and graduate students, extension educators, and professionals operating within the vegetable industry.

The results of the research conducted within each objective have been presented to the target audience of this project and to the general public in different ways, including:

- presentation at in-person professional and academic meetings
- presentation at virtual professional and academic meetings
- webinars, seminars, and webinar series
- the publication of short videos, extension articles, book chapters, and peer-reviewed journal articles
- in-person or virtual one-to-one or small group meetings
- farm visits and demonstrations
- field days and demonstration
- training

Overall, in 2021, the results of the project have been presented through 12 oral presentations and two posters at academic meetings, 4 oral presentations at professional meetings, 4 webinars, 6 guest lectures, a research update and in-service training for extension educators, the publication of 7 extension videos, 2 peer-reviewed book chapters, 6 peer-reviewed

journal articles, 3 extension articles, research reports, a webpage, etc. Moreover, the exchange of information and sharing of research results was achieved through field days, farm visits, in-person demonstrations, one-to-one meetings, exchange of emails, ad-hoc meetings with stakeholders, etc...

The target audience benefited from the project activities through the availability of novel scientific-based knowledge and the advancement of innovative technologies/solutions and information with a focus on improving sustainable vegetable production systems and enhancing vegetable quality useful for their professional education and for their business or specific interest/activity.

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

The general public benefited from the activities of the present project gaining useful information and new knowledge related to sustainable vegetable production systems and vegetable quality through a series of outreach activities including presentations and demonstrations at public events like Ag Progress Days, outreach activities conducted through the Arboretum at Penn State, a STEM virtual camp (video) recorded in collaboration with the Penn State Eberly College of Science and published through WPSU, several meetings, webinars and videos published and available through YouTube, websites, and social media networks, and through several news articles that have reported some of the results of our research and our projects at the state, national, and international level.

### **Impact Statement (Optional)**

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

### **Study suggests “gourmet” microgreens have potential to help provide global nutrition security**

Starting decades ago as fashionable, high-value gourmet greens, today microgreens have gained popularity among consumers for their nutritional profile and high content of antioxidant compounds. A recent study suggested that the tiny plants have the potential to help provide global nutrition security.

An international team of researchers found that these vegetables can be grown in a variety of soilless production systems in small spaces indoors, with or without artificial lighting. With microgreens, people can produce fresh and nutritious vegetables even in areas that are considered food deserts.

The findings are especially relevant considering how the COVID-19 pandemic disrupted food supply chains and revealed the vulnerability of our food system and the need to address malnutrition issues and nutrition-security inequality, which could be exacerbated by potential future emergencies or catastrophes. Nutrient-dense microgreens have great potential as an efficient food-resilience resource.

Microgreens' nutritional profile is associated with the rich variety of colors, shapes, textural properties and flavors obtained from sprouting a multitude of edible vegetable species, including herbs, herbaceous crops, and wild edible species.

With a short growth cycle requiring only minimal inputs of fertilizer, microgreens have great potential to provide essential nutrients and antioxidants. Using simple agronomic techniques, it is possible to produce microvegetables that could address specific dietary needs or micronutrient deficiencies, as well as nutrition-security issues in emergency situations or in challenging environmental conditions.

Consumers could produce microgreens at home using simple tools available in a kitchen. A grower also would need seeds, growing trays, and a growth medium, which could consist of a common peat substrate, a peat and perlite growth mix, or a natural fiber growing mat.

Because microgreens may be used as functional food to enhance nutrition security under current conditions and during future emergencies or catastrophes, microgreen production kits, including seeds, could be prepared, adequately stored, and then made available when needed. Kits could be distributed to vulnerable segments of the population as a short-term nutrition-security resource.

The [research paper](#) was published recently in *Acta Horticulturae*, the journal of the International Society for Horticultural Science.

Project Director

James Ladlee

Organization

Penn State University Park

Accession Number

7001751



## **Penn State Extension: Business, Entrepreneurship, and Economic Development**

---

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

The Business, Entrepreneurship, and Economic Development team seeks to assist in developing data-driven decisions for efficiency, growth, competitiveness, and profitability of food, farm, agriculture, environment, and natural resource businesses and organizations. Critical gaps that reduce risk and enhance opportunities include business development and expansion opportunities, financial management techniques, marketing techniques and strategies, consumer trends, and navigating regulatory environments in each sector.

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

Provide educating and training on the topics of:

- Business Development and Growth
  
- Financial Literacy and Decision Making
  
- Direct Retail and Wholesale Marketing
  
- Food Systems Coordination
  
- Value Chain Coordination

Producing high-quality educational programming allows our Pennsylvania agricultural industry members to access the best available information when making decisions that affect their business. The overall goal of the educational programming team is to provide high-quality, research-driven, objective information to enable the industry to understand, grow, and meet changing market demand. Extension has traditionally tended to emphasize its focus on issues important to agricultural and rural places and people, yet our commitment and mission encompass all communities, including suburban and urban places.

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

- Growing the Craft Brewing Economy: 98.3% of the 232 participants who were surveyed will change their behavior based on knowledge gained during the webinar.
  
- Animal care apprenticeship program: "I think this is an excellent idea and one that our industry and farmers need. I would be willing to participate as best we could in a program." Survey participant
  
- Butcher School Apprenticeship Program: Graduates six apprentices, all currently employed

- Empowering Local Food Buyers
  - 70% of buyers reported intending to source from next year
  - “we made 1,068 transactions ( 23,670 items in 180 minutes) about one sale every 10 seconds.” produce auction manager and auctioneer
- Helping producers evaluate market opportunities:
  - 75% of market channel matchmaking attendees indicated they are likely to change market channels as a result of the program.
  - “As a result of this workshop I will plan with better qualitative metrics.” program participants
- Pocono Farm to School Action Plan
  - A County Farm to School Action Plan was developed for the school districts.
  - Local Producers were engaged in Farm to School Programing (either purchases, visits, and/or planning). Meetings were hosted during the grant period with producers and nutrition service directors to determine the available product, pricing, and scheduling; develop a list of possible options to source locally for student taste tests; explain rules and regulations to serving local foods in a school setting; and explain about institutional procurement and the bidding process.
- Farm Sense
  - Offered to 34 participants, FarmSenSe provided training for farmers to access to over \$2,550,000.00 in borrowed funds
- Farm Markets
  - Farmers Market Manager Forum
    - Monthly meeting of market managers to share best practices and resources with 24 to 40 managers attending monthly.
  - Farmers Markets & COVID-19 Presentation
    - From Events to Essential
    - Farm Markets post COVID
  - Farmers Market Manager Conference
    - Asset Mapping to Build Community Partnerships
    - Conflict Resolution
    - Social Media Marketing Campaigns
    - SNAP Updates

- Inclusive Markets

- Market Matters monthly e-newsletter
- "I was impressed by the fact that the conference provided information useful for markets of different sizes and stages of growth in a wide variety of markets." Program participant
- Ag Viability
  - Agricultural Viability is a new monthly series offered at no-cost by the Energy, Business and Community Vitality Unit. Focused on the business cycle, experts will discuss strategies and best practices to improve your business operations.
    - Agricultural Viability: Avoiding Future COVID and other Disaster Disruptions March 18th with Brook Duer
    - Computerized Financial Records April 15
    - Inventory Methods May 20
    - Payment Methods for your Farm & Food Business June 17th with Sarah Cornelisse
    - Becoming Bankable July 15th with M & T Bank
    - Early Succession Planning August 19
    - Planning the HR Side of your Finances September 16

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

- Farm Market Finder
- Pocono Farm to School Action Plan
  - "Our community was a recipient of a 2019 USDA Farm to School Grant because of the leadership and vision of Alicia Anderson and Linda Falcone. One Farm to School Grant success was connecting local farmers with local school district Food Service Directors. Opening the dialog between the two groups would not have been possible without the Penn State Extension Business and Community Vitality Team existing relationships with local agricultural producers. Together, we will continue to find ways of connecting our community and local food system to decrease dietary related disease and increase access to healthy, nutritious locally grown foods." County Grants Manager
  - Three new Farm to School Grant Applications were submitted in 2021.

**Impact Statement (Optional)**

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

**Improving the agricultural value chain in PA craft beer**

In 2019 Pennsylvania ranked second among the states for volume of craft beer production.

Penn State Extension conducted a PA Craft Brewer study to explore the raw material buying habits of the craft brewers in Pennsylvania and what influences the goal of this program is to help PA agricultural producers and processors better understand the motives and trends of the craft beer industry and how they might collaborate.

The findings show that buying locally produced inputs is a priority for 48 percent of breweries that responded to the survey (depending on the question, about 100 breweries responded). Ninety-six percent of the respondents somewhat or strongly agreed that buying local is good for the local economy, and 81 percent of them somewhat or strongly agreed that buying local means more money for farmers.

Both barley and hops grown in Pennsylvania are subject to mold, fungus, and pests, so many farmers hesitate to enter these markets until they understand the potential profit and build business relationships with enough craft brewers to make the startup and management costs work. Penn State Extension offers research-based resources and startup budget templates for growing hops.

Extension educators are facilitating conversations between growers and brewers to increase the amount of PA agriculture dedicated to craft beer. Educational materials on production for the craft brewing industry and collaborations that improve the processing value chain of hops and grain production are just a few of the resources Extension has worked to develop.

With funding from the Pennsylvania Malt and Brewed Beverage Industry Promotion Board, Penn State Extension is collaborating with CNC Malting in Butler, PA, to increase hops processing, storage, analysis, and sales to brewers. CNC Malting added hops drying, pelletizing, and storage to their services, in addition to their grain drying and contract malting. Before CNC's introduction into the hops processing market, Western Pennsylvania hop farmers had only one known pelletizer to process their hops into a more stable product for craft brewers.

Pennsylvania growers and Penn State Extension aim to increase processing opportunities so that more growers can enter the market, increase the amount of hops grown in the state, and increase the amount of PA-grown hops that goes into Pennsylvania craft beer.

The Pennsylvania craft beverage industry has the potential to create a significant indirect economic impact on PA agriculture. With over \$1 billion in direct economic impact from craft brewery and brew pub sales, jobs, and industry spending, the craft beer industry can also affect those businesses on the value chain that produce inputs. From production to processing, and distribution to marketing, there is a market for locally grown.

## Enhancing Rural Economic Opportunities, Community Resilience, and Entrepreneurship

Project Director

Stephan Goetz

Organization

Penn State University Park

Accession Number

1014522



## Enhancing Rural Economic Opportunities, Community Resilience, and Entrepreneurship

---

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

This project seeks to enhance rural economic opportunities and entrepreneurship and to evaluate factors and policies affecting the resiliency of rural communities. The contributions from the Penn State Agricultural Experiment Station will focus on county-level determinants and impacts of both county-level economic resilience and entrepreneurship development.

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

The following activities and outputs mark significant progress toward the overall goal of understanding the causes, consequences, and distribution of rural opportunities, resilience, and entrepreneurship.

Our collaborations with several partners to advance scholarship on rural opportunities, resilience, and entrepreneurship in light of the pandemic have resulted in several publication series, including one on changes in unemployment claims in Pennsylvania under COVID-19 (Kelsey, Goals 1A, 1B, 1E); a data brief series looking at household food sufficiency in

Pennsylvania (Goetz and Schmidt, Goals 1A, 1B); and a forthcoming report on county-level COVID impacts in Pennsylvania (Alter, Goal 1A). A special issue of *Choices* magazine (published by the Agricultural and Applied Economics Association) was prepared in collaboration with C-FARE and the Regional Rural Development Centers, with Goetz serving as co-editor. The issue was themed “Rural Development Implications One Year After COVID-19” (Goal 2C). It includes two papers by NE1749 partners (Davis and Whitacre), looking at rural childcare and rural broadband through the lens of the COVID-19 pandemic (Goal 1D).

Work is underway on year one of a three-year USDA NIFA-funded project looking at ways to support farmers and ranchers seeking to launch or expand agritourism enterprises. The project is led by Schmidt and includes partners at Penn State (including Goetz), University of Vermont, and University of Oklahoma. Colorado (Thilmany) is contributing in the capacity of an advisory board member. Primary goals of this project are to develop and disseminate practical information that will allow rural communities and owners of small and medium-sized farms to benefit from the growing consumer interest in on-farm experiences. The project will be the first effort to examine the laws, regulations, and level of support for agritourism in each state and compare them with a set of economic indicators, analyzing why some counties are more effective at supporting agritourism enterprises. The team also will use social network analysis to understand how agritourism operators interact with one another and supporting organizations (Goals 1A, 1D, 1F, 2D).

Goetz and Schmidt also carried out research on the role of female farmers in the U.S., showing that female-owned farms in the U.S. are more common in areas that are closer to urban markets, that engage in agritourism activity, and that offer greater access to childcare. The findings offer important insights into how best to serve this population. (Goals 1D, 1F). Project participants in Wisconsin (Deller) and Pennsylvania (Schmidt and Goetz) are continuing this line of inquiry in a research collaboration to investigate the impact of female farmers on community wellbeing, using economic and health community-wellbeing measures. Our preliminary results suggest that controlling for relevant socioeconomic variables, counties with a higher share of female farmers have a lower poverty rate, income inequality, and higher rate of business birth and business growth rate, but they face higher housing fiscal stress. In addition, these counties experience a higher life expectancy, lower percentage of reported fair or poor health and lower average number of physically unhealthy days (Goals 1A, 1B, 1F).

With funding from Penn State’s College of Agricultural Sciences, Alter launched an interdisciplinary community resiliency research and engagement project with Dr. Justine Lindemann (Penn State), titled “Building More Democratic and Equitable Urban Extension Practices through Translational Research and Engagement.” The primary goal of this project is to translate research pertinent to urban communities and systems into practical, collaborative interventions that address issues of significance within those systems and for those communities. A manuscript is under review for publication in 2022 in a special issue of *Socio Ecological Practice Research* (Goals 1A, 1C).

A report published in December 2020, “Understanding Pennsylvania Agriculture,” provides a graphic update on the number of farms, land in farms, agricultural product sales, farm incomes, and information on farm operators by county in Pennsylvania in 2017. Our findings show that although small farms produce only a tiny fraction of Pennsylvania’s total agricultural output, they support billions of dollars’ worth of economic activity while helping to preserve farmland and adding to the diversity of the state’s agriculture (Alter, Goal 1F). Alter also carried out pre- and post-Great Recession sectoral economic analysis for PA counties. A report is forthcoming (Goal 1B).

Goetz, through his role as NERC RD Director, continued work with Colorado (Thilmany) on a USDA AMS cooperative agreement led by the University of Kentucky, exploring the impacts, adaptations, and innovations of COVID-19 on U.S. local and regional food systems, which resulted in a webinar series and several published fact sheets (Goal 1D), which are archived on the project website: <https://lfsccovid.localfoodeconomics.com/>.

Project members contributed book chapters to a forthcoming book, titled “Building Rural Community Resilience Through Innovation and Entrepreneurship” (Routledge) and edited by Dr. Charlie French (UNH, Goals 1A, 1C, 1F, 2C). The book is a result of a research fellowship held by Dr. French and sponsored by NERC RD (Goetz). Contributions by project members include:

- Fortunato, Michael W. P. and Alter, Theodore R. (Forthcoming 2022) “Embracing Uncertainty and Antifragility in Rural Innovation and Entrepreneurship,” in *Rural Innovation and Entrepreneurship*, Charlie French (University of New Hampshire), editor, Routledge.
- Goetz, Stephan J., Meadowcroft, Devon, and Han, Yicheol (Forthcoming 2022) “The Geography of U.S. Rural Innovation and Entrepreneurship” in *Rural Innovation and Entrepreneurship*, Charlie French (University of New Hampshire), editor, Routledge.

An article co-authored by Alter on entrepreneurial ecosystems (Goal 1C) was written this year and is under review for publication in 2022:

- Fortunato, M.W.P. and Alter, T. R. (Forthcoming 2022) “Interactional Theory as a Keystone of Creativity, Innovation, Democracy, and Learning in Action” in Mark A. Brennan and Gene Theodori (eds), *Interactional Theory in Practice: Implications for Community and Local Development*, *Special Issue of Local Development and Society*.

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

The research milestones and outputs described above contribute to the overall science base in the field of rural community and economic development. Academics can use findings from these activities as a tool for further inquiry; practitioners can use them for enhancing and strengthening community-based programming; policy makers can use them to inform local decisions. For example, our findings on the role of female farmers in the U.S. can be used by other researchers as the basis for further study, and by agricultural service providers and policy makers to adapt their programming and policies to address some of the unique needs of female farmers suggested by the findings.

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

The nation depends on rural areas and residents for provision of services such as agricultural, forestry, and energy production. Improving the economic opportunities, resilience, and entrepreneurial ecosystems of rural communities benefits society as a whole, because it positions rural residents to be strong contributors to the American economy. For example, the scholarship shared by project members in the newly published book, “Building Rural Community Resilience Through Innovation and Entrepreneurship,” will help researchers and practitioners strengthen the rural innovation ecosystems in which they work, which in turn will benefit the economic outcomes for rural businesses, their communities, and the overall competitiveness of the American economy.

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

- Workshops were held for extension educators and faculty on organizational issues in translational research and extension in urbanizing and urban contexts. Further, presentations made at various venues (see below) provided research updates to research and Extension audience members. As in previous years, several graduate assistantships were funded by studies and research associated with this project. Training opportunities are also included for postdocs.
- Results have been disseminated through academic and popular publications, as well as virtual workshops, webinars, videos, presentations, publicly published reports, press releases and social media to communities of interest which include policymakers, practitioners, and the public. Findings also have been disseminated to academics and scholarly audiences through various papers or via academic journal articles.
- Throughout the next reporting period we will continue to produce publications surrounding our advancements in researching community resiliency, community engaged scholarship, entrepreneurship, and rural development. Masterclasses and workshops for disseminating knowledge and best practices are also planned. We also will continue to work on the short- and longer-term county-level economic and broader impacts of COVID-19. This also includes assessing how the disease is impacting the food system. Research on the role of entrepreneurial ecosystems in business, community, and regional development will be a central focus of our work. We will continue to work on agritourism related issues. Work is expected to conclude on our NIFA-funded agricultural clusters project with New Jersey (Rutgers). In addition, we expect to complete our research on the relationship between the farm and non-farm economies in different regions of the U.S.
- Peer-reviewed publication with DOI: Schmidt, Claudia, Stephan J. Goetz, and Zheng Tian. “Female Farmers in the United States: Research Needs and Policy Questions.” *Food Policy* 101 (May 2021): 102039. <https://doi.org/10.1016/j.foodpol.2021.102039>.

## Impact Statement (Optional)

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

### Determining characteristics of female-owned farmers in the U.S. to better serve this population

More than one in eight U.S. farms was operated by a woman in 2012, but little is known about these farms. A [paper](#) published in the journal *Food Policy* examined U.S. female farmers' characteristics and factors associated with county-level female farm shares using U.S. and agricultural census data.

Findings show that U.S. female farmers pursue agricultural practices distinctly different from male farmers. Female farm shares are more common near metropolitan core counties and that their presence is associated with agritourism activity and horticultural and small livestock production. More female-owned farms are found where average farm size is below 50 acres, annual farm sales average less than \$10,000 per farm, and direct-to-consumer sales are more prevalent. Access to childcare is an important factor in the location of female-owned farms. More research is needed to analyze the increasing importance and impact of female farmers in the U.S. By understanding how female-owned farms are unique, we can start to learn how best to serve this population.

Critical Issue

## Developing Biologically Based Materials & Products

---

### [Mycotoxins in a Changing World](#)

Project Director

Gretchen Kuldau

Organization

Penn State University Park

Accession Number

1024721



### **Mycotoxins in a Changing World**

---

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

Organic corn producers have a limited number of tools to minimize the presence of fungal mycotoxins in the grain. Our focus is on the impact of using different cover crops as means to accomplish this goal.

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

We conducted a field study to assess if corn plants grown in soils that had previously had different cover crops in the soil had lower amounts of fungal toxin and less ear rot disease. Cover crops including pea, crimson clover, tillage radish, canola, triticale, and oat were planted in early fall. The following spring after the cover crops were tilled under corn plants were planted. At the time of ear formation 10 ears from each of four cover crop plots and fallow plots were inoculated with *Fusarium graminearum*, *Fusarium verticillioides*, or water as a control. At ear maturity ears were harvested and evaluated for ear rot disease severity. In contrast to our previous work, we did not see significant differences between the treatments. We are evaluating our method of inoculation and also the impact of weeds in the plots as possible explanations for these results. This work helps us refine our methods and prepare for the upcoming field season.

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

The target audience will benefit from this work when the results will provide guidance about cover crop selection for organic maize production.

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

As the demand for organic food products increases, the public will benefit from the availability efficiently produced organic food such corn-based products, and meat products such as chicken that are fed corn.

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

Publication Results:

Duffeck, M. R., Bandra, A. Y., Weerasooriya, D. K., Collilns, A., Jensen, P. J., **Kuldau, G. A.**, Del Ponte, E., and Esker, P. 2021. Fusarium head blight of small grains in Pennsylvania: unraveleing species diversity, toxin types, growth and triazole sensitivity. *Phytopathology*, doi:10.1094/PHYTO-02-21-0070-R

Oghenekaro, A. O., Oviedo-Ludena, M. A., Serajazari, M., Wang, X., Henriquez, M. A., Wenner, N. G., **Kuldau, G. A.**, Navabi, A., Kutcher, H. R., and Fernando, W. G. F. 2021. Population genetic structure and chemotype diversity of *Fusarium graminearum* populations from wheat in Canada and north eastern United States. *Toxins*, 13, 180. <https://doi.org/10.3390/toxins13030180>.

Geiser, D. M., Al-Hatmi, A., Aoki, T., Arie, T., Balmas, V., Barnes, I., Bergstrom, G. C., Bhattacharyya, M.K. K., Blomquist, C. L., Bowden, R., Brankovics, B., Brown, D. W., Burgess, L. W., Bushley, K., Busman, M., Cano-Lira, J. F., Carrillo, J. D., Chang, H.-X., Chen, C.-Y., Chen, W., Chilvers, M. I., Chulze, S. N., Coleman, J. J., Cuomo, C. A., de Beer, Z. W., de Hoog, G. S., Del Castillo-Múnera, J., Del Ponte, E., Diéguez-Urbeondo, J., Di Pietro, A., Edel-Hermann, V., Elmer, W. H., Epstein, L., Eskalen, A., Esposto, M. C., Everts, K. L., Fernández-Pavía, S. P., da Silva, G. F., Foroud, N. A., Fourie, G., Frandsen, R. J.N., Freeman, S., Freitag, M., Frenkel, O., Fuller, K. K., Gagkaeva, T., Gardiner, D. M., Glenn, A. E., Gold, S., Gordon, T., Gregory, N. F., Gryzenhout, M., Guarro, J., Gugino, B. K., Gutiérrez, S., Hammond-Kosack, K., Harris, L. J., Homa, M., Hong, C.-F., Hornok, L., Huang, J.-W., Ilkit, M., Jacobs, A., Jacobs, K., Jiang, C., Jimenez-Gasco, Maria del Mar, Kang, S., Kasson, M. T., Kazan, K., Kennell, J. C., Kim, H., Kistler, H. C., **Kuldau, G. A.** (Author), Kulik, T., Kurzai, O., Laraba, I., Laurence, M. H., Lee, T., Lee, Y.-W., Lee, Y.-H., Leslie, J. F., Liew, E. C.Y., Lofton, L. W., Logrieco, A., Sánchez López-Berges, M., Luque, A. G., Lysøe, E., Ma, L.-J., Marra, R. E., Martin, F. N., May, S. R., McCormick, S., McGee, C. T., Meis, J. F., Migheli, Q., Mohamed Nor, Nik Mohd Izham, Monod, M., Moretti, A., Mostert, D., Mulé, G., Munaut, F., Munkvold, G. P., Nicholson, P., Nucci, M., O'Donnell, K., Pasquali, M., Pfenning, L. H., Prigitano, A., Proctor, R., Ranque, S., Rehner, S., Rep, M., Rodríguez-Alvarado, G., Rose, L. J., Roth, M. G., Ruiz-Roldán, C., Saleh, A. A., Salleh, B., Sang, H., Scandiani, M., Scauflaire, J., Schmale, D., Short, D. P., Šiši?, A., Smith, J., Smyth, C. W., Son, H., Spahr, E., Stajich, J. E., Steenkamp, E., Steinberg, C., Subramaniam, R., Suga, H., Summerell, B. A., Susca, A., Swett, C. L., Toomajian, C., Torres-Cruz, T. J., Tortorano, A. M., Urban, M., Vaillancourt, L. J., Vallad, G. E., van der Lee, T., Vanderpool, D., van Diepeningen, A. D., Vaughan, M., Venter, E., Vermeulen, M., Verweij, P. E., Viljoen, A., Waalwijk, C., Wallace, E. C., Walther, G., Wang, J., Ward, T., Wickes, B., Wiederhold, N. P., Wingfield, M. J., Wood, A. K.M., Xu, J.-R., Yang, X. B., Yli-Matilla, T., Yun, S.-H., Zakaria, L., Zhang, H., Zhang, N., Zhang, S., & Zhang, X. (2021). Phylogenomic analysis of a 55.1 kb 19-gene dataset resolves a monophyletic *Fusarium* that includes the *Fusarium solani* Species Complex. *Phytopathology*® <https://doi.org/10.1094/PHYTO-08-20-0330-LE>

### Impact Statement (Optional)

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

Fusarium head blight (FHB) is one of the most important fungal diseases of small grains, including wheat, barley, and oats. It is caused mainly by the fungus *Fusarium graminearum*. Fusarium releases toxins that can harm human and animal health. If Fusarium toxin is detected above certain very low levels, a farmer's grain loads will be rejected. For example, there is zero tolerance to very low tolerance for Fusarium toxin in malting barley, because the brewing process would magnify the toxin, making the resulting beer toxic.

FHB causes about 5–12% loss in the field for small grains in Pennsylvania each year, amounting to an average loss of \$4–7.5 million annually.

*Fusarium* spp. may be evolving in response to fungicides, so continued surveillance is needed.

In this study, 461 isolates were obtained from symptomatic wheat, spelt, barley, and rye crops grown across Pennsylvania in 2018 and 2019. Researchers assessed the fungal isolates causing infection throughout the state and found that 90% were *F. graminearum*. They also evaluated sensitivity to fungicides in vitro, among other things, for a subset of isolates.

This study confirmed the dominance of *F. graminearum* in causing FHB in Pennsylvania. The researchers concluded that the management tools we have for FHB, including small grain varieties that are moderately resistant and well-timed fungicide application, are quite effective in controlling the amount of FHB in small grain crops in Pennsylvania.

## Farm Safety Program

Project Director

Chris Houser

Organization

Penn State University Park

Accession Number

7001699



## **Penn State Extension Farm Safety Program**

---

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

### **Overview of the Need for Agricultural Safety and Health Programming**

According to NIOSH, agriculture ranks among the most hazardous industries in the United States. Farmers and farm workers are at very high risk for fatal and nonfatal injuries; and farming is one of the few industries in which family members including youth and older workers are also at risk for fatal and nonfatal injuries. According to the US Department of Labor, each year more than 2 million youth under the age of 20 are exposed to farm-related safety hazards. Up to 12,000 youth are injured annually on US farms. Vehicles and transportation incidents are the leading source of farm fatalities, generally accounting for more than one-third of all fatalities and severe injuries. A total of 39 farm and agricultural-related fatalities were recorded in Pennsylvania in 2020. This is a significant increase in fatalities from the previous 5-year average.

The diversity of agricultural safety and health educational opportunities continues to grow as new and diverse groups enter the agricultural arena. According to the National Agricultural Statistic Service (NASS), the average age of a PA farmer is 56 years and nearly 30% of agricultural producers are over 65 (NASS, 2017). Aging farmers tend to have limited mobility, age-related disabilities, strength and flexibility limitations, arthritis, and a slower reaction time which can lead to injury. Pennsylvania has the highest percentage (14%) of young farmers in the U.S. and 25% of the state's agricultural producers have nine years or less experience in agriculture (NASS, 2017). Women consist of 35% (31,449) of the agricultural producers in the state (NASS, 2017). Pennsylvania has the largest population of Amish in the U.S. with more than 80,000 people. (Young Center, 2020). Of the 12 states with at least 1 million Hispanics, Pennsylvania saw the fastest population growth, 38% from 2010 to 2019. Latinxs play a critical role in agriculture and the overall US workforce and economy, and their influence increasing. With the cities of Philadelphia and Pittsburgh serving as anchors of the state, PA has seen an uptick in urban agriculture. Outreach activities within growing industries such as micro-farming, hydroponics, and farm-to-table can increase ethnic/racial/linguistic diversity.

There is a never-ending list of agricultural safety and health topics and audiences as we strive to reduce agricultural injuries and fatalities.

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

Through the PDP process, a national survey was conducted to gain information about Penn State's Agricultural Rescue program and there were 481 fully completed responses. The Ag Rescue program conducts most of its trainings in Pennsylvania but does go out of state to provide training classes. There is a charge to the first responders for the course and some courses provide EMS Con Ed to participants. Over the years there has been a decrease in the number of farmers and first responders, and this is a real factor in the event of an agricultural emergency because there are fewer first responders who are familiar with agricultural worksites. The ag rescue program provided multiple modules to train responders in the necessary steps to ensure the best outcome in an emergency. Through the survey, participants were able to rate their knowledge before and after taking the eight modules. Prior to training, the means ranged from 1.91 to 2.5 but after the training the mean score for knowledge gain rose to 3.42 – 3.74. The first responders were asked how the training influenced change and adoption of practices. The results were very positive with 62.5% adopting guidelines for properly stabilizing a farm tractor/machine, 87.5% utilizing available resources, 60% building a network with farmers and for repair shops, and 60.49% incorporating emergency prevention and farm safety education measures into their activities. These changes make a life saving difference in the event of an agricultural emergency.

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

Economy- In regard to safety, the economy is always a factor when you are encouraging agricultural producers to improve safety features on their equipment or make upgrades. This was a difficult financial year for many producers, so most producers only purchased what they viewed as necessities for their operation.

Public policy changes/Competing programmatic challenges: The primary factor during the past year was meeting restrictions because of COVID-19. All the agricultural rescue courses include both classroom learning and hands-on practical training. These restrictions made it unrealistic to keep up with the demand of classes and other organizations with less restrictions began to target our markets.

Extramural funding – The Ag Safety and Health team is funded primarily by grants, but this also limits what we can do outside of grant objectives and deliverables. Two new grants were funded, and another is being submitted. Based on the need for agricultural rescue training evident in the PDP process, there is a need for grant funds for this program and to expand the program to meet the need.

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

In February 2021, customer impact surveys were sent to 17 customers who had received assistive technology or modifications in the 2018 and 2020 calendar years. Sixteen of the 17 customers responded to the survey. Survey results showed the changes in the farm operations from the 16 customers. The acquisition of assistive technology is a process that can take a considerable amount of time and the changes with OVR has significantly impacted this process. However, even with the small number of customers surveyed we are seeing some positive impacts in their farm operation which can also provide positive benefits for the local community. For example, an increase in herd size can impact the amount of feed purchased, increased workforce equates to someone in the community having employment, increased buildings and structures can equate to business provided to a local construction firm and materials purchased, etc. Production agriculture is extremely important to that farm family, but their success and failure also impacts the local community and tax base. Therefore, PA AgrAbility is looking broadly at evaluation to determine if impact from AgrAbility can be measured past the individual farm operation. In addition to the quantitative data, below are qualitative responses from two farmers surveyed:

- o “Operation has improved due to more independence and ability to take care of animals and planting/harvesting crops.”
- o “It is a lot easier packing eggs and faster, also gives more time to address the chickens needs. The egg packer is great!”

### **Impact Statement (Optional)**

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

### **Study reveals agriculture-related injuries more numerous than previously known**

Agriculture has long been listed among the ten most dangerous professions in the country. Penn State researchers looked at agriculture-related emergency room admissions across the U.S. over a recent five-year period using a new method. They found that for the 5-year period from 2015 through 2019, more than 62,000 people were treated in emergency departments for nonfatal, agriculture-related injuries.

Nearly a third of ag-related injuries involve youths. Small farms are family-oriented businesses, and often they have all their family members helping out. Children who are helping out or visiting the farm are exposed to hazards that they may not understand or know how to react to.

Getting a better handle on the number of agriculture-related injuries and how they occur is important because if we understand why they happen, it's much easier to prevent them.

The established method for counting ag-related injuries does not include data for self-employed farmers and family members or workers on farms with fewer than 11 employees, which is most farms.

The new analysis queried the U.S. Consumer Product Safety Commission's National Electronic Injury Surveillance System for all cases using the location code “farm” and relevant keyword searches.

The mean age estimate of the injured population was 39 years old, with ages ranging from 1 to 95. Almost two-thirds of patients were male, and almost 80% were white. Approximately 30% and 22% of those injured were youth and elderly patients, respectively. These age groups are usually not present in the typical workforce but are involved in agriculture.

Most injuries occurred from April through September. The most common injuries were fractures, open wounds, and amputations. Most accidents involved a vehicle, most commonly a tractor.

The [study](#) was published in the *Journal of Agromedicine*. The Nationwide Insurance Endowment for Ag Safety and Health contributed to funding for this work.

Critical Issue

## Promoting Environmental Resilience

---

### **Beneficial Use of Residuals to Improve Soil Health and Protect Public, and Ecosystem Health**

Project Director

Heather Preisendanz

Organization

Penn State University Park

Accession Number

7000254



### **Impacts of Wastewater Irrigation on PFAS in Groundwater and Crop Tissue**

---

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

The presence of per- and polyfluoroalkyl substances (PFAS) has become a topic of urgent emerging concern as the public becomes increasingly aware of the near-ubiquitous presence of these compounds in water utilized for drinking and agricultural operations. The chemical structures of PFAS are difficult to degrade, causing PFAS to persist in wastewater effluent and become introduced into the environment when treated effluent is discharged to surface water bodies, spray-irrigated in beneficial reuse systems, or land-applied as biosolids. The impacts of long-term spray-irrigation of treated wastewater on water and crop quality in agroecosystems are largely unknown, but have the potential to affect human and ecological health.

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

To understand the spatiotemporal trends of 20 PFAS compounds at the Living Filter, water samples were collected bi-monthly in fiscal year 2021 from the University's wastewater effluent and each of the site's 13 monitoring wells. Additionally, crop tissue was collected at the time of harvest to assess PFAS presence in corn and tall fescue grown at the study site. Data from the monitoring wells were compared to federal guidelines for PFAS in drinking water to assess potential human health impacts of the spray-irrigation activities on water quality. Additionally, dairy rations were used to estimate the amount of PFAS that livestock would consume from hay and corn silage grown at the Living Filter site.

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

This study represents a comprehensive assessment of PFAS occurrence at a long-term beneficial reuse facility. Overall, ten PFAS compounds were found across the site, with average total PFAS concentrations of 58 ng/L in the wastewater effluent and concentrations as high as 155 ng/L in the monitoring wells. Although it appears the occurrence of PFAS across the site is nearly ubiquitous, the impacts to groundwater appear to be minimal, with no PFAS values exceeding federal health advisories of 70 ng/L. PFAS concentrations showed little seasonal variability, while spatial patterns of PFAS concentrations in the monitoring wells followed the general groundwater flow direction, with the lowest concentrations of PFAS on the periphery, upgradient portions of the field that were least influenced by irrigation activities and highest concentrations in the irrigated areas that receive the accumulated groundwater flow. Several PFAS compounds were detected in crop tissue samples collected at both irrigation and non-irrigated portions of the site, suggesting that PFAS enter the food chain when these crops are fed to livestock. The vast majority (>87%) of the PFAS present in the feed were short-chain compounds, including PFBA,

PFHxA, and PFPeA, whereas long-chain compounds comprised the remainder of the PFAS in the feed. Future research is needed to determine potential risks to livestock health and the potential implications of PFAS presence in meat and dairy products, including milk.

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

This study demonstrated that even after four decades of intensive spray-irrigation activities, PFAS levels in the underlying groundwater did not exceed the EPA's health guidelines of 70 ng/L for PFOS and PFOA. This is consistent with the management of the site to maintain groundwater concentrations of nitrate below 10 mg-N/L. Further, the data demonstrate that short-chain PFAS compounds do enter the food chain from spray-irrigation activities. However, more research is needed to understand the potential risks PFAS presence in meat and dairy products, including milk.

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

This research provided training for two graduate students, including one MS and one PhD student, and one undergraduate student.

The results have been disseminated to the scientific community through the publication of a conference paper. A full paper has been submitted to the Journal of Environmental Quality for peer review. This research has also been presented at several professional society meetings, including: The American Society of Agricultural and Biological Engineers, the Northeast Agricultural and Biological Engineering Conference, and the Emerging Contaminants in the Environment Conference.

The results have been disseminated to the general public through several Penn State extension webinars.

**Impact Statement (Optional)**

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

**Windows of opportunity crucial for cutting Chesapeake nutrient and sediment loads**

A Penn State–led study found that the vast majority of nutrients and sediment washed into streams flowing into the Chesapeake Bay are picked up by deluges from severe storms that occur on relatively few days of the year. This finding may offer clues for cleaning up the bay.

A small percentage of locations and events contributes to the vast majority of total annual pollution loads entering the bay. These findings stress the importance of concentrating our efforts on “hot moments”—not just “hot spots”—across impaired watersheds to achieve water-quality-restoration goals.

Researchers analyzed eight years of data from 108 sites in the Chesapeake Bay Program’s nontidal monitoring network. They looked at daily-scale records of flow and corresponding loads of total nitrogen, total phosphorus, and total suspended sediment at each gauging station from 2010 through 2018. Then they applied a data analysis method normally used in economics to determine the temporal distribution of pollution loads throughout the years. In this way they were able to measure the degree of temporal inequality of nutrient and sediment loads across the study years.

This approach allowed them to identify periods of time and corresponding flow conditions that must be targeted to achieve needed load-reduction goals across the watershed. This is the first time a uniform method has been proposed for quantifying and identifying “hot spots” for nutrient and sediment transport. The [paper](#) was recently published in *Environmental Research Letters*.

The study’s conclusions urge watershed planners and managers to use a temporal framework to develop low- and high-flow targets for nitrogen, phosphorus, and sediment loads specific to each watershed within the bay’s 64,000-square-mile basin. The seven states in the Chesapeake’s watershed have been federally mandated since 2010 to continually reduce nutrient and sediment loads reaching the bay.

Until now, processes for determining how to reduce total annual pollution loads at a watershed scale have targeted spatial, not temporal, components of inequality—hot spots, not hot moments.

The new analysis offers some insight into why we haven't met goals for restoring the bay's water quality. There's been a lot of frustration around how much time and money have been spent and the number of best-management practices that have been adopted. We're still significantly behind where we need to be, especially for nitrogen in Pennsylvania.

Now that we know the dynamics of nutrient and sediment transport across the bay watershed, we may need to think differently about how we approach our goals. If we can't deal with the highest flows from severe storms, which are becoming more intense due to climate change, then we need to design a system that is more efficient at achieving load-reduction goals during low flows.

Rather than an "everything, everywhere, all-the-time" approach, focusing on hot spots and hot moments reduces the problem to finding "the right solutions in the right places that work at the right time" approach.

## [Fates of Soil Carbon and Nitrogen in Agricultural Systems](#)

Project Director

Armen Kemanian

Organization

Penn State University Park

Accession Number

1020049



### **Nitrous oxide emission when using organic sources of fertility**

---

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

Both organic and conventional agriculture rely to a greater or lesser degree on organic sources of fertility that include animal manure and green manure. Green manures are cover crops that are killed prior to planting the cash crop and in the cases of agriculture with tillage incorporated in the soil. We have found in prior research that a large flush of nitrous oxide, a greenhouse gas, can occur after animal manure and animal manure incorporation. Among our interests is to develop both a better understanding of the processes enabling such large and damaging emissions, and the technology to reduce these emissions.

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

We are conducting the second of series of experiments designed to understand and manipulate these emissions. We completed the first year of an experiment in which the type of tillage (or smart tillage approaches) and type of cover crop (or smart cover cropping) was altered and nitrous oxide and other ancillary variables measured through the growing season. The experimental site is at Agronomy Farm of Penn State at Rock Springs. In addition, we published a paper reporting the results of the first experiment in this series. This paper includes a novel interpretation of the emission of nitrous oxide which relates to fast consumption of oxygen after green manure incorporation. The low but non-zero oxygen concentration seem to cause the optimal conditions for large nitrous oxide emissions. Emissions of nitrous oxide exceeded 10 kg/ha of N during the corn phase if emissions are calculated by linear interpolation. These emissions are very high and climate wise obliterate even optimistic (an undocumented) gains of soil organic carbon. Ongoing work using other methods to estimate cumulative emissions from discrete measurements suggests that emissions can be much larger, and that therefore this research is of critical importance to design climate-smart agricultural systems.

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

There are three target audiences to consider. First, researchers in the academic community which by accessing our research and publicly available data will focus their own efforts on this important subject. The data of this research has been made available and at least one research team has incorporated it to a database for further analysis. Second, both consultants, analysts and policy makers are increasingly interested in developing means to reduce greenhouse gas emissions from every sector of the economy. Nitrous oxide is a major target for agriculture, as our sector emits about 70% of the global

anthropogenic emissions of this gas. Third, producers seeking to produce agricultural commodities sustainable are eager to learn means to refine their management of organic inputs. Our research has opened a new dimension on the combined management of crops through tillage and the use of organic amendments.

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

As stated before, nitrous oxide is the third most important greenhouse gas behind carbon dioxide and methane. Since it is emitted mostly in ag-related activities, we have a professional mandate to contain these emissions and to do in a way that improves overall nutrient management and the environmental footprint of agriculture. It is impossible to manage something that we do not know. Our research is shedding light on management and processes that emit large amounts of nitrous oxide, or in other words, we found a large leak of a greenhouse gas (and a plant nutrient - nitrogen) and therefore have a chance to reduce this leak for the benefit of producers and society at large.

### **Impact Statement (Optional)**

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

### **A semi-commercial case study of willow biomass production in the northeastern United States**

Exploring the opportunities and challenges associated with new commodities that can fit production systems in the region is a priority for the College of Agricultural Sciences. Shrub willow (*Salix* spp. and hybrids) is a biomass crop well adapted to the northeastern United States with its moist soils, cold winters, and mild summers. It is high yielding, fast growing, requires few inputs, has multiple stems, and re-sprouts after being cut. Shrub willow reaches heights of 5–7 meters in 3 years. The harvested wood is usually sold in chip form. The wood chips have low ash and are easily stored for relatively long periods. Non-energy uses include mulch, animal bedding, and fiberboard.

To test its potential in production conditions, a research team assessed the biomass productivity of six willow cultivars in a 14.5-hectare field in Pennsylvania through two rotation cycles of 3 years each. The team compared the realized and biophysical yield potential. They also evaluated the relationship of yield with plant density and harvest efficiency.

The realized yield of the best cultivars was about 8,000 kilograms/hectare/year of dry matter (or approximately 4 tons/acre), well below the calculated harvestable potential of 14,000 kilograms/hectare/year. Uniform stands of willow without planting gaps may maximize yield with 8,000 plants per hectare, but upright cultivars may benefit from higher densities.

Harvest is relatively slow at 1 hectare/hour or 20,000 kilograms/hour in the longest rows with optimal ground conditions, which makes the harvest cost per hour high.

Biotic stresses built up gradually during the 7 years of the experiment, affecting two cultivars severely. The cultivar 'Preble' was defoliated by a growing population of willow leaf beetle. The cultivar 'Fish Creek' was affected by two fungal diseases and suffered a major stand loss in winter 2019/2020. Both examples justify breeding for insect- and disease-resistance.

The moderate harvestable yield and high harvest cost imply that in the northeastern United States, the viability of willow for bioenergy with carbon capture and storage as a tool to reduce carbon dioxide emissions may depend on the provision and monetization of additional ecosystem services that shrub willow provides. These include carbon storage, pollinator hosting, reduction of water runoff, and soil nutrient retention.

The [work](#) was recently published in *Agronomy Journal*.

Critical Issue

## **Supporting Integrated Health Solutions**

---

### **Interactions Among Arthropods, Pathogens/Parasites, and Hosts**

Project Director

Erika Machtinger

Organization

Penn State University Park

Accession Number

7000334



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

The primary goal of the proposed research is to better understand arthropod ecology and behavior to improve management methods in and IPM framework. The purpose of this research is to use both fundamental and applied approaches to learn more about the biology and ecology of arthropods, their parasites and pathogens, and their hosts to improve control strategies and to improve our understanding of the natural world.

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

During this reporting period, we established the team that conducts the research and education related to the project. We have established research programs related to the goals of the project and will continue to execute those methods.

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

The target audience is the general public who are exposed to vectors, and commodity groups that have plants and animals that are susceptible to parasites and pathogens. Our continued focus on arthropod behavior and ecology will provide the framework to develop novel IPM tools and improve current tools. These technologies will reduce the impact that pest species have on our stakeholder groups, whether they are a threat to their health or their economic livelihood. In addition, we developed education materials hosted through Extension on vectors and vector-borne diseases that will benefit our stakeholder groups as they learn how to prevent vector bites.

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

The broader public is one of our target audiences as they are exposed to vectors when outside. Our educational materials have provided the general public with ways to prevent vector bites and protect their animals from vector bites as well. Our research focus is to reduce the impact of parasites and pests on crops and livestock and to human health by improving control technologies.

**Impact Statement (Optional)**

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

**PlantVillage team protects food supply in Horn of Africa amid COVID, locusts**

Penn State researchers responsible for [PlantVillage](#), a mobile app that helps farmers diagnose crop diseases and monitor pests, helped African farmers overcome challenges related to desert locusts and COVID-19.

PlantVillage was built to be a land grant university in a phone, integrating artificial intelligence, satellite-derived knowledge, and cloud computing.

PlantVillage now has more than 130 full-time team members across 10 countries who are dedicated to projects ranging from climate change adaptation technology to pest diagnosis and advising farmers. PlantVillage is the core engine of the newly launched USAID Innovation Lab on Current and Emerging Threats to Crops and continues to power multiple transboundary systems for the United Nations Food and Agricultural Organization.

In early 2020, an infestation of desert locusts—fueled by unusual weather related to climate change—threatened food security in Ethiopia, a country ranked as one of the hungriest in the world. Even a small part of an average swarm of locusts (about one ton) eats the same amount of food in one day as nearly 2,500 people, according to the Food and Agriculture Organization (FAO) of the United Nations.

The locust invasion was Ethiopia's worst in 25 years, and COVID-19 compounded the problem by creating restrictions on personnel and equipment. The locusts then spilled over into Kenya, which had not seen such swarms in 75 years.

The expectation was that up to 35 million people would lose food. It was imperative to use remote reporting to track swarms and deliver pesticide treatments faster, all while keeping those on the front lines safe.

PlantVillage and Mediae, a media company based in Nairobi, worked closely with other organizations, such as FAO, to develop an awareness campaign about locusts that would encourage citizen reporting. The Penn State scientists used their know-how to create a smartphone app, eLocust3m, that made it easy for farmers and citizens to report locust sightings. Air and ground control teams used this information to target and destroy swarms.

Television, radio, and text messages in five local languages reached 16 million farmers over six months. The project and several other initiatives were responsible for protecting the food security of 36.6 million people and avoiding \$1.56 billion in cereal and milk losses, according to the FAO. This success story on the power of technology to combat locusts was covered in the [New York Times](#).

The power of technology—artificial intelligence and the use of smartphones connected to satellites—has opened up massive opportunities for African farmers as they struggle to cope with climate change and other biotic stressors. The same approach could be used to crowdsource critical information related to other climate change–driven disasters. This offers much hope for an uncertain future as we try to grow food for a future population of 10 billion under a climate changed world.

## **Engineering for food safety and quality**

Project Director

Ramaswamy Anantheswaran

Organization

Penn State University Park

Accession Number

1023215



## **Engineering for food safety and quality**

---

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

In response to changing consumer demands, the U.S. food industry needs to develop innovative manufacturing processes to develop safe, high-quality, nutritious, and healthy food products. The goal of this project is to investigate novel processing technologies to provide safe foods with the highest quality.

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

Cocoa roasting (Dr. Anantheswaran):

Cocoa beans are rich sources of polyphenolic compounds with anti-inflammatory and enzyme inhibitory activities which could aid in diabetes and obesity management. Cocoa processing steps like hot air roasting have been found to reduce the total polyphenol content (TPC) by 50% or more. Superheated steam roasting has been found to retain higher TPC levels in cocoa compared to hot air roasting. Changes in TPC might not be indicative of changes in bioactivity of these cocoas. Some studies have shown that the digestive enzyme inhibitory and anti-inflammatory properties of cocoa remain intact under certain processing conditions irrespective of TPC loss. This suggested that the composition of polyphenols rather than the total amount may be a more important determinant of bioactivity.

Hot air roasting at three temperatures (150°C, 175°C, 200°C) was compared to superheated steam roasting in terms of its impact on the polyphenol composition, bioactivity and flavor development in cocoa. Cocoa beans roasted using these two methods were analyzed for TPC using Folin-Ciocalteu assay. Cocoa beans roasted for 30 min at 150°C with superheated steam exhibited 30-50% higher levels of desirable volatile compounds like pyrazines compared to equivalent hot air roasted beans. The procyanidin composition of beans prepared by these different roasting methods is being compared using LC-MS, offering insight into the higher bioactivity of superheated steam roasted cocoa.

Pulsed UV light technology (Dr. Demirci):

Pulsed UV light is a novel technology that can be employed to eliminate microorganisms in foods. Last year, we evaluated pulsed UV treatment to inactivate *Escherichia coli* and *Enterococcus faecium* on eggs. Shell eggs were surface inoculated with *E. coli* or *E. faecium* and treated with pulsed UV light using a modified egg candling conveyor that provided complete rotation of eggs under a flashlamp. Treatments of 1.0, 2.4, 3.1, and 4.9 J/cm<sup>2</sup> resulted in microbial reductions (Log<sub>10</sub> CFU/cm<sup>2</sup>) of 3.83,

4.26, 4.28 and 4.62 for *E. coli* and 2.04, 3.12, 3.11 and 3.82 for *E. faecium*, respectively. There was no negative impact of the PUV light treatment on percent fertility and hatchability. This study demonstrated a successful application of pulsed UV light as an effective antimicrobial intervention for table and hatching eggs.

On another project, we investigated the germicidal response pulsed ultraviolet (PUV) light on the surface of food-grade conveyor belt materials. Four conveyor belt types including: a stainless-steel chain-link belt, a polytetrafluoroethylene (PTFE)-coated fabric belt, a solid pliable polymer belt, and a rigid-linked polymer belt, were evaluated for the inactivation of *E. coli* K12-NSR strain and lactic acid bacteria (LAB). For samples inoculated with *E. coli* K12-NSR, the surface condition (soiled or unsoiled) by treatment interaction was significant for microbial inactivation on the surface of the rigid polymer linked belt. Microbial reduction ranged from 0.74 to 5.04 log<sub>10</sub> CFU/cm<sup>2</sup> for *E. coli* K12-NSR and 0.63 to 4.61 Log<sub>10</sub> CFU/cm<sup>2</sup> for LAB for the evaluated treatment parameters. The results of this project demonstrated that pulsed UV light is an effective means of decontamination for conveyor belts during food processing.

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

The ultimate goal of this project is to enhance food safety and nutritive quality of processed foods intended for consumption by the general public. Mathematical modeling of temperature distribution and efficacy of sanitation practices of food processing equipment will contribute to enhancing food safety of processed food products. In order to produce safe foods, novel technologies such as pulsed UV processing are being investigated for various food processing applications.

This project involved collaboration between four scientists and training of four graduate students.

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

The stakeholders impacted by this project include students, food industry, extension agents, state and federal agencies, and consumers. Collaborations among engineers and food scientists across the nation can effectively result in effective training of food engineers and development of advanced food processing technologies. Development of improved processing technologies for cocoa can result in additional nutritional benefits for consumers from the consumption of chocolate products. Development pulsed UV technology enhances the food safety associated with processed food products for the consumers.

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

### **Peer-reviewed publications with digital objective identifier (DOI).**

Cassar, J.R., L.M. Bright, P.H. Patterson, E.W. Mills, and A. Demirci. 2021. The efficacy of pulsed ultraviolet light processing for table and hatching eggs. *Poultry Science*. 100(3):100923. [DOI:10.1016/j.psj.2020.12.021](https://doi.org/10.1016/j.psj.2020.12.021). *NIFA acknowledged*

Cassar, J.R., E. Mills, A. Demirci, and J. Campbell. 2021. Pulsed ultraviolet light treatment of chicken parts. *Meat and Muscle Biology*. 5(1): 28, 1–8. [DOI: 10.22175/mmb.12256](https://doi.org/10.22175/mmb.12256). *NIFA acknowledged*

Cassar, J.R., E.W. Mills, and A. Demirci. 2021. Pulsed ultraviolet light decontamination of meat conveyor contact surfaces. *Food Science and Technology International*. In- print. DOI:10.1177/10820132211049610. *NIFA acknowledged*

Lele, S.L., Takhar, P.S. & Anantheswaran, R. C. 2022. Modeling heat transfer during hot water sanitization of a commercial mushroom slicer. *Journal of Food Process Engineering* (in press). *NIFA acknowledged*

### **Impact Statement (Optional)**

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

### **Pulsed ultraviolet light treatment of chicken parts is an effective antimicrobial treatment**

Raw chicken provides all of the necessary conditions needed to harbor and support the growth of spoilage and pathogenic microorganisms during refrigerated transportation and storage. The most prevalent foodborne pathogens associated with raw chicken include *Salmonella* and *Campylobacter*. A report by the Foodborne Disease Active Surveillance Network

indicated that the numbers of foodborne illness outbreaks caused by *Salmonella* and *Campylobacter* reported in the United States in 2012 were 535 and 23, respectively. Between 2009 and 2015, the CDC reported 123 chicken-associated foodborne illness outbreaks, which accounted for 9.6% of all outbreaks in the U.S.

With increasing production and consumption of chicken, it is appropriate to investigate the functionality and effectiveness of microbial reduction interventions and the qualitative effects they have on chicken. The effectiveness of pulsed ultraviolet (PUV) light applied to chicken parts on a moving conveyor was evaluated for inactivation of *Escherichia coli* on the surface of raw boneless/skinless (B/S) chicken breasts, B/S chicken thighs, and bone-in/skin-on chicken thighs. The distance from the flashlamp and conveyor speed were set to deliver different amounts of energy to the surface of the products.

Results showed that PUV light treatment is effective at modestly reducing *E. coli* (up to ~90% reduction) on the surface of chicken thighs, breasts, and skin. Microbial reduction increased with exposure to greater total energy and the absence of skin on the product surface. Microbial reduction was generally greater for B/S chicken parts than for bone-in/skin-on parts.

Lipid oxidation and changes in color of chicken samples were evaluated as quality markers after the strongest PUV light treatment. Lipid oxidation was measured directly after treatment and at 1 day, 2 days, and 5 days post-treatment. PUV light treatment did not produce significant changes in lipid oxidation values for each product type. Color parameters were not significantly affected by PUV light treatments. This study indicates that PUV light applied to the surface of raw chicken parts on a moving conveyor is an effective surface antimicrobial treatment and induces minimal change in quality of the product over a 5-day storage period under aerobic conditions. The [article](#) was published in *Meat and Muscle Biology*.

### **Retail/Food Service/Consumer Food Safety**

Project Director

Catherine Cutter

Organization

Penn State University Park

Accession Number

7001743



### **PSU Extension Retail/Food Service/Consumer Food Safety Team**

---

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

The Pennsylvania Department of Agriculture requires retail food service operations to have one person certified in food safety to meet regulatory requirements. While not mandated to receive training, volunteer organizations are also vulnerable to foodborne illness outbreaks. Many Pennsylvanians preserve food at home through canning; therefore, proper education around botulism control is critical.

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

During the program year, eight Penn State Extension Food Safety Educators indicated they helped over 511 different food service facilities meet certification requirements. Representatives of these establishments estimate they employ some 3200 workers. A total of 127 registrants attended an in-person or online course, *Cooking for Crowds: A Volunteer's Guide to Safe Food Handling* which gives volunteers training on safe food handling practices that can reduce the risk of a foodborne illness outbreak. A series of live webinars were conducted throughout the program year on all types of home food preservation. The webinars included a lecture on the science of home food preservation, tested techniques for preserving a safe product, and live demonstrations of proper preservation practices. Additionally, 394 dial gauge canners were tested for accuracy.

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

According to a 2018 Public Health Report, the economic burden of a single outbreak to a restaurant can range from \$3968 to \$2.2 million depending on type of pathogen, number of people affected, lost revenue, lawsuits, legal fees, and other costs. If one case of foodborne illness is prevented in each of the 511 Pennsylvania facilities that received food safety training from Penn State Extension, the total economic savings to these establishments can range between \$2.7 million and \$1.1 billion per

year.

According to a 2015 report in the Journal of Food Protection, in Pennsylvania the cost per foodborne illness case ranges from \$1190 - \$1960. Assuming each of the 171 individuals that participated in a Cooking for Crowds program represent one non-profit organization and one case of foodborne illness is prevented in events conducted by these Pennsylvania non-profit organizations by attending a Penn State Extension training, the potential economic savings to Pennsylvania is between \$200,000 to \$335,000 per year.

Sixty-one percent (240) of tested pressure canner dial gauges required adjustment when processing foods or replacement. Without such testing, the potential for improperly processed low acid foods is increased which could result botulism, a deadly foodborne illness.

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

The COVID-19 pandemic continued to impact programming efforts. Guidelines by the University around resumption of in-person programming related to social distancing and mask wearing limited return to normal face-to-face programs on food safety for most of the program year. With social distancing requirements, class sizes were severely limited based on the size of the facility. In some cases, normal locations for classes were simply too small to even be able to offer a class. For these reasons home food preservation and food safety programming for volunteer groups remained virtual for most of the program year.

The ServSafe™ Food Manager Certification was offered in person during the year, however attendance was low compared to pre-pandemic registrations. This was perhaps due to the significant economic impact on the restaurant industry. A September 2021 report from the Pennsylvania Restaurant and Lodging Association<sup>1</sup>, indicates a 77% decline in indoor dining due to the delta variant and 80% indicate continued lower sales volume compared to pre-pandemic sales. These and other issues may have resulted in attendance at a food safety certification class being less of a priority than other more immediate issues for restaurant operators.

Other external factors impacting program efforts include PDA food regulations for food safety certification, other competing organizations offering the same programming, educator responsibilities in other program areas, and the challenge to provide food safety education to clients with English as a second language. A part-time Spanish language ServSafe instructor role is currently posted.

### **Impact Statement (Optional)**

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

#### **Retail/Food Service/Consumer Food Safety Extension team helps prevent foodborne illness on several fronts**

The Retail/Food Service/Consumer Food Safety Extension team offers various trainings to meet the needs of different audiences. The Pennsylvania Department of Agriculture requires retail food service operations to have one person certified in food safety to meet regulatory requirements. While not mandated to receive training, volunteer organizations serving food are also vulnerable to foodborne illness outbreaks. Many Pennsylvanians preserve food at home through canning; therefore, proper education around botulism control is critical.

During the program year, eight Penn State Extension food safety educators helped more than 511 different food service facilities meet certification requirements through the ServSafe training program. Representatives of these establishments estimated that they employ some 3,200 workers.

A total of 171 registrants attended an in-person or online course, Cooking for Crowds: A Volunteer's Guide to Safe Food Handling, which gives volunteers training on safe food handling practices that can reduce the risk of a foodborne illness outbreak.

A series of live webinars was conducted throughout the program year on all types of home food preservation. The webinars included a lecture on the science of home food preservation, techniques for preserving a safe product, and live demonstrations of proper preservation practices. Additionally, 394 dial gauge canners were tested for accuracy.

According to a 2018 article in the journal *Public Health Reports*, the economic burden of a single foodborne illness outbreak to a restaurant can range from \$3,968 to \$2.2 million, depending on type of pathogen, number of people affected, lost revenue, lawsuits, legal fees, and other costs. If one case of foodborne illness is prevented in each of the 511 Pennsylvania facilities

where managers received ServSafe food safety training from Penn State Extension in this program year, the total economic savings to these establishments could range from \$2.0 million and \$1.1 billion per year.

According to a 2015 report in the *Journal of Food Protection*, in Pennsylvania the cost per foodborne illness case ranges from \$1,190 to \$1,960. Assuming that each of the 171 individuals who participated in a Cooking for Crowds program represents one nonprofit organization and that just one case of foodborne illness is prevented in events conducted by each of these Pennsylvania nonprofit organizations by attending this Penn State Extension training, the potential economic savings to Pennsylvania is between \$200,000 and \$335,000 per year.

Sixty-one percent (240) of tested pressure canner dial gauges required adjustment when processing foods, or replacement. Without such testing, the potential for improperly processed low-acid foods rises, which could result in botulism, a deadly foodborne illness.

## **Vector-Borne Disease Programs**

Project Director

Elise Gurgevich

Organization

Penn State University Park

Accession Number

7001701



### **FY21 Penn State Extension Vector-Borne Disease Program Results**

---

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

Ticks accounted for over 75% of reported vector-borne diseases across the United States; cases were concentrated primarily in the eastern part of the country. Ticks and mosquitos are the two vectors that transmit the most common vector-borne pathogens. Pennsylvania ranks first in the number of Lyme disease cases since 2000; some estimates suggest 50,000-70,000 residents struggle with tick-borne diseases annually. Commonwealth of Pennsylvania initial education and awareness campaigns have been limited to posting CDC signage in Pennsylvania State Parks and State Forest Districts and improving the network of surveillance for both ticks and tick-borne disease at various universities, including Penn State. There is still a great deal of work needed to educate the public on the vector-borne disease spread by ticks and mosquitoes and preventive action that can be taken to reduce exposure and disease risk.

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

In FY21 Penn State Extension used previously collected needs assessment data on the public's understanding of vector-borne diseases transmitted by ticks and mosquitos, preventive actions to reduce risk, and their desire for more information. This information was used to develop programming in four focus areas, 1. Prevention of Vector-borne Disease, 2. Control of Vectors, 3. Identification of Vectors and 4. Risk and Threats.

The team produced materials to address acute parasite challenges. This included a research publication (below) and an educational fact sheet about atypical infestations of winter tick on captive white-tailed deer in Pennsylvania, which is a growing commodity group.

Tick and mosquito education was provided to specific groups, including professional pest manager schools and the Pennsylvania Vector Control Association. Information was delivered via webinar format primarily due to the ongoing pandemic. However, team programming was high quality and was one of the top three webinars at the annual Pennsylvania Farm Show event in Harrisburg, PA.

Seven peer-reviewed publications related to this program were published during the year, including:

**Tiffin, H. S., M. J. Skvarla, E. T. Machtinger.** Tick abundance and life-stage segregation on the American black bear (*Ursus americanus*). *International Journal for Parasitology*. *Accepted*. <https://doi.org/10.1016/j.ijppaw.2021.10.004>

**Poh, K. C., E. T. Machtinger.** 2021. An Extension of their work; Extension's role in vector-borne disease education. *American Entomologist* 67: 22-25. <https://doi.org/10.1093/ae/tmab006>

Machtinger, E. T., R. M. Nadolny, B. T. Vinyard, L. Eisen, A. Hojgaard, S.A. Haynes, L. Bowman, C. Casal, and A. Y. Li. Spatial heterogeneity of sympatric tick species and tick-borne pathogens emphasizes the need for surveillance for effective tick control. *Vector-borne and Zoonotic Diseases Accepted* <https://doi.org/10.1089/vbz.2021.0027>

Machtinger, E. T., J. E. Brown, and E. R. Burgess, IV. Landscape distribution and abundance of animal-associated adult filth flies on commercial swine facilities in North Carolina, US. *Medical and Veterinary Entomology. Accepted* <https://doi.org/10.1111/mve.12542>

Machtinger, E. T., H. R. Springer, J. E. Brown, and P. U. Olafson. Sudden mortality in captive white-tailed deer with atypical infestation of winter tick. *Journal of Medical Entomology*. 58: 1962-1965 <https://doi.org/10.1093/jme/tjab043>

Evans, J. R., K. C. Poh, M. Skvarla, and E. T. Machtinger. The Keds are alright: community collection of ticks (Ixodidae and Ixodidae) and keds (Diptera: Hippoboscidae) from hunter-harvested deer. *Annals of the Entomological Society of America*. <https://doi.org/10.1093/aesa/saab003>

Milholland, M. T., L. Eisen, A. Hojgaard, R. M. Nadolny, E. T. Machtinger, J. M. Mullinax, and A. Y. Li. 2021. Surveillance of ticks and tick-borne pathogens in suburban natural habitats of central Maryland. *Journal of Medical Entomology* 58: 1352–1362 <http://doi.org/10.1093/jme/tjaa291>

In addition, Extension educators reached the public indirectly by conducting interviews with two radio programs (WITF Smart Talk and WESA) and for one article in USA Today.

A significant focus of the past year was collecting media and writing storyboards for a series of short, on-demand videos that will be produced in 2022. This year also included the preparation of “Tick Kits” to remove ticks from humans, horses, and household pets. These kits would be promoted in all relevant vector-borne disease programs when instructions on proper tick removal procedures are discussed.

All of these support the goal of providing research-based education to increase awareness of vector-borne disease spread by ticks and mosquitoes and preventive action that can be taken to reduce exposure and disease risk.

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

Improving education to reduce tick-bite risk has never been more important. Vector-borne diseases have tripled in the U.S. in the past 13 years, and 75% of those cases are tick-borne. Mild winters will reduce tick mortality, potentially increasing populations and tick-borne disease risk. Currently, no landscape-level methods for tick control have been demonstrated to eliminate or even significantly reduce tick-borne disease risk; therefore, it is critical that those at high-risk for exposure are provided with the educational tools to protect themselves.

Educational interventions effectively increase understanding and active involvement in preventing vector-borne diseases. In a career-focused survey, respondents in land management and wildlife conservation that self-identified as having high specific knowledge of tick-borne disease were more likely to report high overall intentions to engage in tick-borne disease prevention.

The vector-borne disease team focused on both general education and education to specific stakeholder groups, including horse owners, pet owners, hunters, pest managers, and farmers.

Our webinars during the pandemic have been well-received. The “Protecting Yourself from Tick Bites” program had 255 participants. 85% of respondents of the post evaluations indicated the information was extremely useful. Comments included that the program was excellent, very informative, presented well, and was time well spent. Live webinar participants were able to have their questions answered during the presentation, and all registrants received a link to the recording, which contained closed captioning.

We also have produced products aimed at changing the behavior of the public to incorporate tick bite prevention methods. One example of this is the “Tick Check Shower Hanger.” This product was produced in English and Spanish and was sensitive to tick identification on a spectrum of skin tones.

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

The information delivered in the various formats will help protect people and their families and their animals, including pets and livestock. This will ultimately help reduce disease incidence in people and economic losses resulting from veterinary issues caused by vectors.

## Impact Statement (Optional)

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

### Research and extension needs regarding filth flies in animal agriculture to increase profitability and sustainability

Many flies are considered serious pests of livestock, poultry, swine, sheep, goats, horses, and other farm animals. "Filth flies" are so named because of their close association with animal feces, food waste, or carrion. These pests can negatively affect animal welfare and contribute to considerable production losses. They are also important potential vectors for many pathogens of animals and people.

Management of filth fly pests in particular, including the house fly, stable fly, horn fly, face fly, and little or lesser house fly, has been a research and Extension priority of veterinary entomologists for decades and significant strides have been made. An indication of the potential return for focusing on these flies comes from the eradication of the primary screwworm from North America, which resulted in \$1.3 billion in economic benefit in the U.S.

But ongoing changes to animal husbandry and production practices, coupled with an increasing development of behavioral and physiological resistance to insecticides, require renewed focus on new and more effective management strategies.

Filth flies damage farm animals through direct biting and associated blood loss, tissue damage, and stress. Indirect damage includes pathogen transmission and animal disturbance.

One estimate of annual U.S. losses to the beef industry (feedlot and stocker cow/calf) from horn fly, stable fly, and face fly was \$1.88 billion in 1991 (\$3.9 billion today, adjusted for inflation).

In the poultry industry (layers and broilers), a 2001 study estimated that more than \$29 million was spent annually (\$46 million in 2022 dollars) on pesticide to control house flies, not including labor costs.

An [article](#) recently published in the *Journal of Integrated Pest Management* by members of a multistate research project team lays out needs for future filth fly management and education:

- Since the 1980s about half of the veterinary entomology faculty positions at U.S. research universities have been lost. There is a critical need to increase the number of veterinary entomologists trained in applied animal agriculture to conduct research into improved methods to manage insect pests associated with animal production.
- We lack detailed loss estimates related to the activity of these flies for most animal commodities. There is a need for comprehensive economic analyses for each filth fly species affecting each animal industry, with analysis including losses and expenses.
- A better understanding of the physiological mechanisms associated with resistance and adaptive chemical control methods is required to manage and prevent insecticide resistance.
- Additional research on the association of filth flies with pathogenic microbes or parasites is needed across animal production sectors and housing types, particularly within the context of the One Health framework. The role of flies in the spread of antibiotic-resistant pathogens or in the transfer of antibiotic resistance genes among bacteria must be further evaluated.
- There is a need for testing of new pest management technologies.
- Producers need education on identifying and managing filth flies in their animals.
- Nuisance lawsuits may make animal agriculture unsustainable in some areas. This can be a significant economic crisis for rural areas that rely on jobs associated with animal production. We need trained experts to identify pests in these lawsuits and suggest mitigating tactics.

- o With the rising human population, food production demands are expected to increase, so the development, implementation, and adoption of effective biosecurity measures focused on filth flies is needed for all animal production systems.

Type

Projects/ Programs

**Projects / Programs without a Critical Issue**

**0**

Not Provided