USDA

United States Department of Agriculture

Agricultural Research Service

2022 ANNUAL REPORT

ARS REPORT ON SCIENCE

Contents

Who the Agricultural Research Service is

Dr. Simon Liu, ARS Administrator

The **Agricultural Research Service (ARS)** is the U.S. Department of Agriculture's chief scientific in-house research agency. Our job is finding solutions to agricultural problems that affect Americans every day from field to table. ***In 2022 alone, ARS produced 51 new licenses, 40 new patents, and published 3,935 peer-reviewed journal articles.*** ARS has 90+ locations, 8,000 employees, and 660 research projects spanning 15 national programs.

Mission

ARS delivers scientific solutions to national and global agricultural challenges.

To fulfill our duties, ARS research must be relevant, which is crucial for ensuring that our work has the potential to make meaningful contributions to the industry, society, or world. There are several factors that can contribute to the relevance of our research. These include the timeliness of the research, the importance of the research question or problem being addressed, the potential practical or societal implications of the research, and the potential that findings will contribute to the existing body of knowledge in the field.

Vision

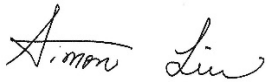
Global leadership in agricultural discoveries through scientific excellence.

Innovation is the key to scientific excellence leading to agricultural discoveries. To realize our vision, ARS must expand our innovation culture and make innovation a part of our DNA. Innovative research can take many forms, such as developing new theories or models, using novel techniques or methods, or applying existing ideas or approaches in new contexts or to new problems.

Core Values

Scientific excellence, creativity, innovation, integrity, leadership, collaboration, accountability, transparency, diversity, respect, inclusiveness, and public service.

ARS is delivering scientific tools and innovative solutions for American farmers, producers, industries, and communities. However, long-term challenges such as a changing climate, and rapidly evolving issues such as a global pandemic, require agility, innovation, and relevance, or AIR, in our response. As the ARS Administrator, I am filled with hope and determination as we rise to meet these challenges and deliver scientific solutions to national and global agricultural challenges with agility, innovation, and relevance as the common thread throughout our work. To fulfill our mission, ARS must be agile in responding to these challenges in a timely fashion. We must become even more agile to quickly adapt to new technologies, changing environments, or unexpected challenges in our research process. This can involve a variety of different skills, such as the ability to pivot to new research questions or methods, to effectively collaborate with colleagues or stakeholders, to quickly learn new techniques or technologies, or to effectively communicate findings and progress. This Annual Report on Science is one way we communicate our findings and progress over the last year. ARS accomplishments span the breadth of our 600+ projects and 15 national programs to offer you a glimpse of some of the most important findings our scientists have discovered. I hope you find them as informative and compelling as I do.

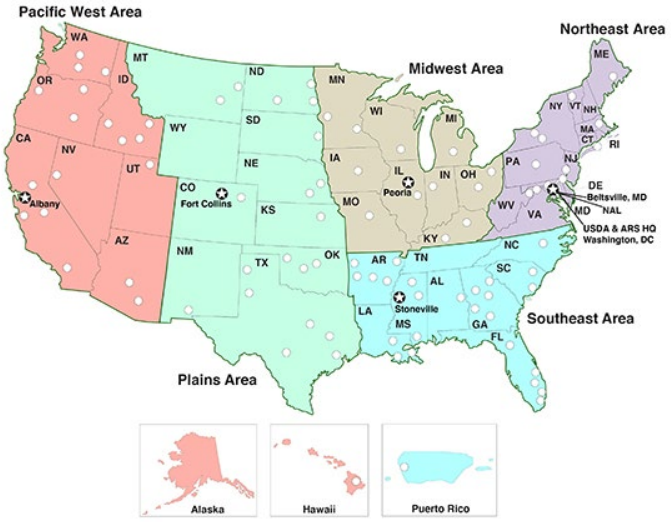


Simon Y. Liu
ARS Administrator

Specialized Infrastructure and Capabilities

ARS has more than 90 research locations featuring cutting-edge facilities and resources. They include:

- Four Overseas Biological Control Laboratories
- U.S. National Arboretum
- National Agricultural Library
- National Bio and Agro-Defense Facility



Scientific Collections and Genebanks, including:

- ARS National Plant Germplasm System
- ARS Culture Collection
- ARS National Rhizobium Germplasm Resource Collection
- National Animal Germplasm Program
- National Invertebrate Genetic Resources
- USDA Nematode Collection
- U.S. National Arboretum Herbaria
- U.S. National Fungus Collections

Premier Networks of Scientific Expertise, including:

- Long-Term Agroecosystem Research (LTAR) network to develop national strategies for the sustainable intensification of agriculture
- USDA Climate Hubs for providing region-specific, climate-informed assistance to agricultural and natural resource managers
- Greenhouse gas Reduction through Agricultural Carbon Enhancement Network (GRACEnet) for promoting sustainability by reducing greenhouse gas emissions from soil
- Resilient Economic Agricultural Practices (REAP) for improving soil health and resiliency through improved management practices
- Partnerships for Data Innovation for developing precision field monitoring systems and managing big data in agriculture
- Breeding Insight for accelerating small breeding programs through the combination of advanced breeding approaches, genomics, and informatics
- Federal LCA Commons for publishing life cycle assessment models and developing federal standards in life cycle assessment modeling
- Ag100Pest for sequencing the genomes of 100 significant agricultural pests (part of the Earth Biogenome Initiative)

ARS National Program Areas

Dr. Steven Kappes, ARS Associate Administrator of National Programs

The Office of National Programs (ONP) is the principal ARS organizational office that assesses the full spectrum of scientific needs of the Agency. ONP leads program direction by developing 5-year National Program Action Plans, reassigning research projects to high priority problems, partnering with ARS Area Directors to address program areas that lack adequate resources, and developing budget recommendations for the Administrator about new research program initiatives. ARS research is organized into National Programs. These programs serve to bring coordination, communication, and empowerment to approximately 660 research projects carried out by ARS. The National Programs focus on the relevance, impact, and quality of ARS research and enable ARS to provide global leadership in agricultural discoveries through scientific excellence.

The ARS national program areas and corresponding national programs are provided in the list below.

Nutrition, Food Safety/Quality

- Human Nutrition (NP 107)
- Food Safety (animal and plant products) (NP 108)
- Product Quality and New Uses (NP 306)

Animal Production and Protection

- Food Animal Production (NP 101)
- Animal Health (NP 103)
- Veterinary, Medical, and Urban Entomology (NP 104)
- Aquaculture (NP 106)

Crop Production and Protection

- Plant Genetic Resources, Genomics and Genetic Improvement (NP 301)
- Plant Diseases (NP 303)
- Crop Protection and Quarantine (NP 304)
- Crop Production (NP 305)

Natural Resources and Sustainable Agricultural Systems

- Water Availability and Watershed Management (NP 211)
- Soil and Air (NP 212)
- Grass, Forage, and Rangeland Agroecosystems (NP 215)
- Sustainable Agricultural Systems Research (NP 216)

ARS Animal Production and Protection Research

Dr. Jeffrey Silverstein, Deputy Aministrator, Animal Production and Protection

The ARS Animal Production and Protection (APP) National Programs improve livestock production efficiency and the health and well-being of livestock, poultry, and aquatic food animals to ensure a safe and wholesome food supply. These research programs provide the scientific information and tools to support U.S. food animal industries in supplying the nutritious animal products required by the nation, competing successfully in worldwide trade, and contributing toward global food security. APP programs also address a wide range of problems facing animal health, including zoonotic and other diseases caused by bacteria, viruses, parasites, prions, and arthropod pests and vectors. Our research produces solutions to protect the health and well-being of U.S. agriculture and the American public.

To achieve these goals, ARS conducts research that:

- Improves food animal production efficiency, industry sustainability, animal welfare, and product quality, while safeguarding animal genetic resources;
- Protects and ensures the safety of U.S. agriculture and the U.S. food supply through improved disease detection, prevention, and control;
- Improves domestic aquaculture production efficiency and product quality while minimizing production impacts on natural resources; and
- Mitigates arthropod vectors and the diseases they transmit to livestock, humans, and other animals, and reduces their economic impact.

Looking ahead, ARS prioritizes the development of precision agricultural management decision tools that will track and manage environmental stress, reproduction, disease, and behavior. ARS also works to improve the use of genomic and transcriptomic data to optimize gene expression in different tissues at different animal developmental stages and produce the best animal products for each production environment. APP promotes the responsible conduct of agricultural science at ARS, including the humane and conscientious use of live animals, through training opportunities by the biosafety and animal welfare staff and by developing effective policies and research monitoring programs.

ARS is co-leading efforts with USDA's Animal and Plant Health Inspection Service (APHIS) to establish a new National Bio and Agro-Defense Facility (NBAF) in Manhattan, Kansas. This state-of-the-art facility will be the first maximum biocontainment laboratory (BSL-3Ag and BSL-4) in the United States and will enable the safe investigation of especially dangerous and deadly pathogens, including emerging and high-consequence zoonotic diseases affecting livestock. NBAF will enhance current research programs and expertise in foot-and-mouth disease, African swine fever, classical swine fever, Japanese encephalitis, and Rift Valley fever. The new facility will also enable ARS to initiate new research and develop expertise in zoonotic disease agents, conduct real-time research in response to disease outbreaks, and enhance our preparedness posture by conducting research gap analyses and prioritizing research to maximize the impact of our research programs. NBAF construction activities are complete; USDA held a ribbon cutting celebration in May 2023, and facility operations will ramp up in 2024 and 2025.

ARS Crop Production and Protection Research

Dr. Nora Lapitan, Deputy Administrator, Crop Production and Protection

The ARS Crop Production and Protection (CPP) National Programs deliver science-based information, genetic resources, superior varieties, high-value crop traits, and technologies for increased crop productivity, economically and environmentally sustainable methods of crop and grassland production, and crop and natural area protection from diseases and pests. Research conducted as part of CPP programs supports the needs of producers, land managers, consumers, workers, the public, and the global community by increasing crop productivity and value; ensuring a ready supply of high quality, safe, appealing, and affordable fiber, feed, ornamentals, industrial feedstocks, and nutritious food and beverages; improving the safety of working environments; advancing environmental protection; and meeting the needs for food security.

To meet these needs, ARS conducts research that:

- Harnesses the genetic potential of plants to transform U.S. agriculture;
- Enhances U.S. agricultural crop productivity, efficiency, and sustainability; and ensures a supply of high quality and safe food, fiber, feed, ornamental, and industrial crops for the United States;
- Improves and expands our knowledge of existing and emerging plant diseases and develops effective and sustainable disease management strategies that are safe for humans and the environment;
- Uses fundamental biological and ecological principles to develop innovative approaches for managing insect pest populations below economically damaging thresholds;
- Develops new control strategies for intractable weeds in cropping systems and invasive plants in natural areas that improve livelihoods and sustain biodiversity; and
- Develops crop production systems that focus on crop diversification options for producers and promote the health of beneficial insects that provide ecosystem services.

ARS is a steward for important national agricultural resources that protect U.S. agriculture. These resources include the National Plant Germplasm System (distributed across 20 locations), Overseas Biological Control Laboratories (five locations), the U.S. National Arboretum in Washington, D.C., and cutting-edge high-throughput phenotyping and sensing technologies housed at the U.S. Arid Land Agricultural Research Center. ARS also delivers important targeted programs, including the Areawide Pest Management Program, National Sclerotinia Initiative, National Plant Disease Recovery System, Pulse Crop Health Initiative, and the AgBioData consortium. ARS is accelerating our understanding of crop and pest genomes by spearheading the following initiatives:

- Breeding Insight, which provides breeders with direct access to and support for customized tools, informatics, and database technologies to adopt modern genomics strategies to their programs. Breeding Insight currently supports grape, blueberry, sweet potato, alfalfa, Atlantic salmon, trout, cranberry, cucumber, oat, lettuce, honeybee, pecan, and strawberry breeding and will expand its support to more than 50 ARS breeding efforts during the next 4 years.
- I5k and Ag100Pest, efforts to sequence the genomes of 5,000 insects and mites, including the top 100 agricultural pests in the United States. To date, ARS scientists have sequenced the genomes of key invasive pests such as the Asian citrus psyllid, brown marmorated stink bug, spotted lanternfly, and northern giant hornet.

Additionally, ARS fosters research synergies that cut across the continuum of scientific disciplines to achieve breakthrough innovations.

ARS Natural Resources and Sustainable Agricultural Systems Research

Dr. Marlen Eve, Deputy Administrator, Natural Resources and Sustainable Agricultural Systems

The ARS Natural Resources and Sustainable Agricultural Systems (NRSAS) National Programs develop technologies and strategies that help farmers, ranchers, and other managers effectively steward the diverse agricultural mosaic that depends on national land, air, and water resources. These diverse landscapes include rangelands and managed pastures for grazing livestock and crop fields—from the most common commodity crops to the most unique and high-value specialty crops—cultivated in every corner of the country. These agricultural systems generate around $600 billion every year in goods, services, and the food we all rely on daily and that are the basis of a strong rural economy. ARS research aggressively seeks to provide the tools, techniques, technologies, and information to ensure the long-term viability, productivity, resilience, and sustainability of these production systems.

The NRSAS research programs investigate and develop tools, technologies, and strategies for:

- Effectively and safely managing watersheds and water resources to sustain and increase agricultural production and water use efficiency while protecting the environment and human and animal health;
- Enhancing and protecting soil resources; managing nutrients and emissions from agricultural soils, livestock production systems, and byproducts; and improving production from agroecosystems to increase their resilience to changing climates;
- Improving management decisions and enhancing the function and performance of rangelands, pastures, forage, and turf agroecosystems while enhancing ecosystem services; and
- Enabling greater productivity, profitability, and natural resource enhancement by using integrated solutions for agriculture.

To achieve these goals, ARS coordinates the Long-Term Agroecosystem Research (LTAR) network, a premier partnership of 18 federal and university agricultural research sites that represent most of the agricultural production regions in the United States. Growing out of the LTAR network, the Partnerships for Data Innovations (PDI) is transforming network data stewardship and has created a “Digital Research Workbench” as the foundation for facilitating data innovation, standardization, automation, and integration, which will accelerate agricultural research. PDI delivers field and researcher-focused data management solutions that catalyze research collaborations, fulfill Agency and Departmental data priorities, inform Big Data analytics, and ensure compliance with federal data access policies. Additionally, ARS partners with the U.S. Forest Service to direct the USDA Climate Hubs, which develop science-based, region-specific information and technologies that provide climate-informed decision-making and assistance to agricultural and natural resource managers. The initial 5-year review of the Hubs confirmed that Climate Hubs’ work and outputs are highly valued and highlighted their strengths in convening, leveraging funds, and expanding climate adaptation practices. ARS is also home for GRACEnet and the REAP program.

ARS Nutrition, Food Safety, and Quality Research

Dr. Pamela Starke-Reed, Deputy Administrator, Nutrition, Food Safety, and Quality

The ARS Nutrition, Food Safety, and Quality National Programs maintain a healthy and safe food supply while improving the economic viability and competitiveness of U.S. agriculture by enhancing the quality and utilization of agricultural products for the benefit of farmers, foresters, producers, industries, processors, producers, and consumers.

To achieve these goals, ARS conducts research that:

- Defines the role of food and its components in optimizing health throughout the human life cycle for all Americans;
- Protects food from microbiological pathogens, biological toxins, and chemical-based contaminants during production, processing, and preparation; and
- Improves postharvest agricultural product quality; develops new uses for plant and animal foods and fiber; and adds value to products while innovating and enhancing the bioeconomy with common and alternative crops through bioprocessing technologies for potential markets such as biopharmaceuticals, specialty bioproducts, industrial biochemicals, and biofuels.

One of the defining features of these programs is an emphasis on food-based approaches to improve human health. The ARS Human Nutrition Research National Program hosts six internationally recognized Human Nutrition Research Centers, as well as smaller research units in four other locations. The centers and locations have core capability for long-term, multidisciplinary, and translational research in high priority areas and premier scientists, state-of-the-science equipment, and facilities for human research across the life cycle. This program leverages unique national resources, including three centers that focus on specific portions of the life cycle. Other centers have programs that maintain the National Nutrient Database of food nutritional composition, track U.S. food consumption patterns through the What We Eat In America survey, determine the impact of agriculture on human nutrition, provide data to inform the development of dietary guidance and national nutrition policy, and help reduce the burden of chronic disease.

The ARS Food Safety National Program plays a critical role in keeping the food supply safe and secure by developing tests and interventions to control or eliminate potentially harmful contaminants—both naturally occurring or deliberately introduced—in agricultural products. The program involves both national and international collaborations and delivers research results and advances to regulatory agencies, commodity organizations, industry, academia, research and extension agencies, and consumers.

The ARS Product Quality and New Uses National Program assures that elite breeder germplasm of grains (wheat, oats, and barley), potatoes, peanuts, citrus and cotton is used in the commercial products for which it was originally developed as well as for alternative uses. Work also focuses on developing knowledge and enabling commercially viable technologies to measure, maintain, and enhance the quality of wood, fiber, fruit, vegetable, chicken, and fish products; assess food allergenicity; harvest and process wood, cotton, wool, and leather; and create new value-added food and non-food products. This research also focuses on using innovative bioprocessing of renewable non-food, low-value plant and animal resources to meet consumer demands for sustainable high-value consumer products, reduce food loss and waste, and generate clean energy that increase producer profits.

ARS Office of International Research Engagement and Cooperation

Ms. Ingrid Watson, Acting Director, Office of International Research Engagement and Cooperation

The ARS Office of International Research Engagement and Cooperation (OIREC) enhances the productivity, effectiveness, and impact of ARS research through mutually beneficial international research projects. USDA's international research cooperation provides solutions to current and future agricultural productivity and sustainability challenges beyond what can be achieved through domestic research alone. OIREC supports ARS leadership in global science and technology engagements so that ARS can identify emerging ideas and solutions wherever they arise, increase the impact of research and development spending, and deliver new knowledge and technologies to those who will benefit from them.

OIREC is the main point of contact for international activities in ARS and coordinates the Agency's international relationships. Working with the ARS Office of National Programs**,** OIREC international affairs specialists catalyze strategic international partnerships that can enhance the productivity, effectiveness, and impact of ARS National Programs and advance the goals of the U.S. government.

OIREC works with ARS and partners with other USDA and federal research entities to:

- Catalyze and manage domestic and international partnerships that enhance the capacity of ARS national programs for addressing critical needs of U.S. agriculture;
- Network with other U.S. government agencies and the international community to promote ARS interests; and
- Manage the Overseas Biological Control Laboratories, which identify and collect natural enemies of invasive species in the United States.

The four strategically located Overseas Biological Control Laboratories enable ARS to study in and partner with countries that are the sites of origin for invasive species, which advances current and future U.S. mitigation efforts:

- The European Biological Control Laboratory (EBCL) in Montpellier, France, has a satellite laboratory in Thessaloniki, Greece. ARS owns and operates the EBCL.
- The Australian Biological Control Laboratory in Brisbane, Australia, is run through a cooperative agreement with Australia's federal research body, the Commonwealth Scientific and Industrial Research Organization.
- The Foundation for the Study of Invasive Species in Hurlingham, Argentina, is operated as a nonprofit research organization partnering with ARS.
- The Sino-American Biocontrol Laboratory in Beijing, China, is run through a cooperative agreement with the Chinese Academy of Agricultural Sciences.

ARS Office of Technology Transfer

Mr. Brian Nakanishi, Deputy Assistant Administrator, Office of Technology Transfer

The ARS Office of Technology Transfer (OTT) encourages, promotes, and facilitates the adoption and commercialization of technology resulting from ARS research, helping to move USDA research discoveries to the marketplace. Although research results are sometimes transferred directly from ARS to end users, the private sector more often serves as the essential delivery mechanism and intermediary between ARS research and the realization of public benefit. Private sector partners facilitate technology transfer by providing the complementary assets needed for the adoption of research outcomes. Such assets may include unique research and manufacturing expertise, capabilities, and facilities; marketing and distribution expertise and capacity; product registration and/or regulation expertise; and investment capital. By providing these assets, private sector partners make investments that increase the impact of ARS research by ensuring research outcomes are widely available.

Because the ARS mission is to transfer technologies for broad public use by the most effective mechanism, ARS pursues patents and licensing principally to incentivize commercialization and to facilitate technology transfer to the marketplace. This is usually the case when complementary investment by the private sector is necessary to commercialize a product, and patent protection is required to protect this investment. In licensing practices, ARS reserves the right to allow use of any intellectual property-protected technology for non-commercial research purposes.

To facilitate technology transfer at ARS, OTT:

- Creates a culture that understands and fosters entrepreneurship and innovation;
- Maintains intellectual property policies and technology transfer mechanisms;
- Ensures an understanding and awareness of technology transfer policies and best practices;
- Communicates the strategic value of technology transfer internally and externally;
- Judiciously uses intellectual property rights to enhance adoption of research outcomes;
- Develops and maintains flexible technology transfer mechanisms that correspond to scientific needs;
- Leads and engages in the Agricultural Research Partnerships Network;
- Leads and engages with the Agricultural Technology Innovation Partnership Foundation;
- Supports small businesses by coupling funds and technologies in collaboration with the Small Business Innovation Research Program of the USDA National Institute of Food and Agriculture;
- Promotes an entrepreneurial culture by piloting the National Science Foundation's Innovation Corps at ARS;
- Recognizes and incentivizes participation in technology transfer activities;
- Stays current on federal policies and best practices in technology transfer; and
- Encourages the implementation of innovative methods for conducting technology transfer.

ARS has also been delegated authority by USDA to coordinate the technology transfer program for all USDA agencies. As part of this departmental coordination, ARS publishes an annual report on technology transfer that reports on the technology transfer of all USDA agencies, including ARS.

The National Agricultural Library

The National Agricultural Library (NAL) sustains the U.S. agricultural enterprise through public access and effective stewardship of agricultural data, literature, and other information resources. Housing more than eight million physical items, NAL is the world's largest collection of agricultural information.

Mr. Paul Wester, Director, National Agricultural Library

As one of five national libraries and the library of the USDA, NAL manages the NAL website (https://nal.usda.gov/), the entry point to all its online resources, including:

- AGRICOLA, USDA's online catalog and index to the agricultural literature;
- PubAg and Ag Data Commons, USDA's "one-stop-shop" for public access to USDA-funded scholarly literature and scientific research data;
- NAL Digital Collections, including digitized content from NAL's Special Collections; and
- DigiTop, the online resource for USDA staff that provides continuing access to licensed electronic resources such as journals, databases, newspapers, and e-books.

By investing in these resources, providing top-notch expertise in library and information science, and collaborating with partners and internal and external stakeholders, NAL:

- Supports USDA's strategic goals for fact-based, data-driven decision-making through NAL's information products and services;
- Delivers unified, easy-to-use, convenient 24/7/365 digital services that are customer-focused and meet customer expectations and needs;
- Works efficiently and effectively, with integrity and customer focus; and
- Provides leadership in agricultural and research library communities to build capacity for effective stewardship of information resources and improving access to agricultural information, supporting the Department's mission.

NAL is a leader in scientific data management and planning, benefiting researchers everywhere. Today's research studies in agriculture are data-intensive—and publishing that data fosters trust and drives innovation in agricultural research.

U.S. National Arboretum

The U.S. National Arboretum (USNA) enhances the economic, environmental, and aesthetic value of ornamental and landscape plants through long-term multidisciplinary research, genetic resources conservation, and interpretative gardens and exhibits. Established in 1927 by an act of Congress and administered by ARS, this premier scientific institution inspires discovery, understanding, conservation, and the love of plants. Through its programs and exhibits, USNA demonstrates the practical application of plant science and human dependence on plants.

Dr. Richard Olsen, Director, U.S. National Arboretum

Located in northeast Washington, D.C., USNA connects people with plants in a serene urban oasis featuring unique collections and gardens connected by restored habitats and natural ecosystems. At 451 acres and with upwards of 700,000 annual visitors, the arboretum is one of the largest and most visited public gardens in the United States.

The USNA is ARS' flagship location for ornamental plants research, which includes:

- Wide-ranging developmental and applied research on trees, shrubs, turf, and floral plants;
- Collecting, preserving, and distributing ornamental crops as a National Plant Germplasm System genebank;
- Operating the official USDA herbarium, which is unique in its taxonomic focus on ornamental, economic, and agricultural crops and their wild relatives;
- Developing superior landscape plants through a program of genetic improvement, evaluation, and introduction to industry stakeholders; and
- Identifying plant pathogens and developing pathogen control technologies, particularly for viruses and bacteria threatening the floral and nursery crops industry.

Additionally, USNA boasts the National Bonsai & Penjing Museum, the most comprehensive collection and display in the United States dedicated to the science and art of bonsai. The museum began with a gift from Japan to the United States in 1976. Both the museum and arboretum are routinely ranked as top destinations in Washington, D.C., and provide unique facilities where public visitors can explore the depth and breadth of ARS research through displays, gardens, and exhibits.

Top 2022 Research Accomplishments

What ARS Does: Improving Crop, Livestock, and Aquaculture Production

Institute of American Indian Arts 1994 Land-Grant Tribal College and University (TCU) land-grant program gardener Teresa Kaulaity Quintana (Kiowa) leads the gardening team, operations, instruction, and outreach for all things related to the campus demonstration garden and greenhouse, in Santa Fe, New Mexico. USDA Photo by Lance Cheung.

Developing New Crop Varieties with Enhanced Traits and Disease Resistance

Researching genetic diversity is key for creating novel sources of resistance in crops and improving their resilience to disease, pests, and pathogens. ARS scientists are developing new crop varieties by exploring gene function, using in vitro production, and tracking differences in DNA sequences to identify genes. In FY 2022 ARS researchers made advances in crop resilience with the development of two Fusarium head blight (FHB)-susceptible wheat cultivars that enable additional resistance research. In addition, ARS scientists are using fluorescent marker proteins in work to control Huanglongbing (HLB) and determine the origin of the bacterium CLas, which causes HLB and is transmitted to citrus trees by the Asian citrus psyllid. They are also leveraging advanced technology for infested tomato plants.

New gene editing system for validating wheat Fusarium head blight resistance gene function. Fusarium head blight (FHB) is a devastating disease in wheat that reduces grain yield and quality. The market value of infected grain is reduced from mycotoxin contamination associated with FHB, and estimates suggest farmers and food processors incur hundreds of millions of dollars in FHB-related losses each year. Gene editing can provide an effective tool to create new sources of resistance but using gene transformation to deliver CRISPR/Cas9 and guide RNA into wheat plants to study is successful in only a few cultivars. ARS researchers in Manhattan, Kansas, developed and optimized a new RNA delivery system to produce transgene-free mutant plants. A major FHB-susceptibility gene was successfully edited in two FHB-susceptible wheat cultivars and the gene-edited trait was heritable in different wheat genetic backgrounds. This gene editing system can be used to create novel mutations for a wide array of applications in wheat breeding, including improving resistance to FHB. (NP 301)

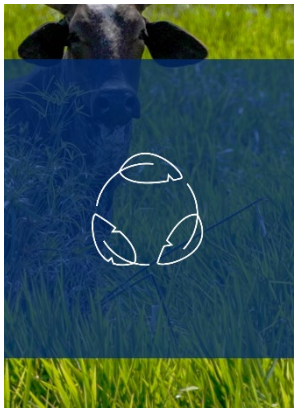
Use of SymbiontTM technology for in vitro production of therapeutic molecules. In work funded by a $15 million 5-year NIFA grant, ARS researchers in Fort Pierce, Florida, and Ithaca, New York, demonstrated that proprietary Symbiont technology can be used for in vitro production of large quantities of therapeutic molecules. The multidisciplinary work, which is also part of a CRADA with the agricultural biotechnology company AgroSource, Inc., demonstrated that symbiont tissue can be cultured in vitro for the cost-effective production of molecules that are secreted into the culture media and continuously harvested. This was demonstrated using fluorescent marker proteins and by production of a special class of antibodies called nanobodies. The collaborating scientists studied the ability to make nanobodies in their Symbiont system because they are also developing nanobodies against effector proteins produced and secreted by the bacterium that causes HLB. These effectors induce HLB disease symptoms in infected citrus plants, and other lines of research indicate that binding antibodies/nanobodies to these effectors prevents disease development. The scientists also demonstrated that functional nanobodies can be produced in plant cells using a gene encoding a nanobody that targets SARS-CoV-2 spike proteins. This nanobody was found to inhibit the interaction of the SARS-CoV-2 spike protein and the surface antigen on mammalian cells that it uses to enter the cell. This work shows that the plant-based Symbiont cells can be used to produce therapeutic molecules, and current research is underway to evaluate the Symbiont system for producing therapeutic candidates to treat citrus HLB disease. (NP 304)

New, highly protective vaccine for Marek's Disease. Repeated emergence of more virulent Marek's Disease Virus (MDV) strains in vaccinated chicken flocks prompted urgent research focused on enhanced Marek's Disease (MD) vaccines. ARS researchers in East Lansing, Michigan, and Athens, Georgia, collaborated with a researcher at Simon Fraser University (Vancouver, Canada) and used innovative, recombinant DNA technology and naturally occurring genetic variation in a targeted gene to develop a new, highly protective MD vaccine candidate. Genomic discoveries and newly developed recombinant vaccine methodology allowed researchers to respond quicky to ever-changing and emerging disease threats on the farm. A next step will include regulatory approval, offering the U.S. poultry producers the

new MD vaccine to reduce mortality and morbidity; improve poultry health, well-being, and production efficiency; and support economic sustainability of the poultry industry. (NP 101)

How new foot-and-mouth disease viruses emerge in nature. Foot and mouth disease (FMD) is a devastating disease of livestock this is easily transmitted, and the virus is capable of persisting without causing disease, which has important implications for FMD control strategies. This phenomenon is called the "carrier state" and was widely perceived as a dead end because of the belief that persistently infected cattle could not transmit the virus to other animals. ARS scientists in Orient Point, New York, demonstrated that when persistently infected carriers of FMDV were exposed to a different strain of the virus, the two viruses exchanged genetic material (recombined) to give rise to new viruses containing distinct parts of each of the parental viruses. This discovery demonstrates a novel process whereby new strains of FMDV may evolve and emerge in the field and contributes towards preparing for a potential outbreak of new and emerging FMDV strains that could pose a threat to the U.S. homeland. (NP 103)

Advancing Sustainable Livestock Production



The ARS Animal Production and Protection research program prioritizes management practices that ensure consumers can access an abundant supply of competitively priced, high quality animal products that enhance human health, while ensuring domestic food security and enhancing the efficiency, competitiveness, and environmental sustainability of the food animal industry. New and efficient processes that provide solutions to developing issues within animal agriculture production, such as industry sustainability, are necessary for safeguarding animal genetic resources. Key FY 2022 accomplishments include researching genetically engineered vaccines, identifying genetic and environmental relationships, and modeling technologies for more sustainable animal agriculture processes.

Modeling liver abscess formation in cattle to reduce antibiotic use. Liver abscesses in cattle result in significant economic costs for producers and the beef packing industry due to reduced growth rates and an increased incidence of rumen acidosis that affects animal health and welfare and reduces carcass value. Unfortunately, liver abscesses are only clearly identified at harvest when organs are inspected, which limits live animal research for identifying causes and solutions. ARS scientists in Lubbock, Texas, and university collaborators developed a real-world, live animal liver abscess model that more closely aligns with the natural development of abscesses in cattle. They used dietary changes and oral infusions of naturally occurring bacteria to increase the identification of cattle with liver abscesses and to evaluate intervention and mitigation strategies that reduce liver abscesses in beef production systems. The model will enable testing of alternatives to antibiotic treatment, reduce the need for antimicrobial use and the potential development of antibiotic resistance, improve cattle health and wellbeing, and improve economic returns at the farm and packer levels. (NP 101)

Optimized cryopreservation of turkey genetic resources. For most livestock species, sperm cryopreservation effectively captures the entire genome. However, in birds, female chromosomes determine gender, so complete genome capture and preservation entails collecting female gonads as well as sperm. Effective cryopreservation is not possible for eggs, so reproductive biology expertise driving female gonad retrieval, preservation, and re-introduction is critically needed in the turkey and across avian species. ARS scientists in Beltsville, Maryland, in collaboration with scientists in Canada, perfected turkey female gonad (ovary) retrieval timing in chicks. They also established an optimized surgical method and timeframe for transplanting ovaries to recipient birds. Results indicate that 91 percent of ovarian grafts were successful if tissue was collected from 7-day old donors and implanted into 2-day old recipients under the surgical process. This discovery represents a major scientific advancement and

provides industry and research institutions with a powerful tool to preserve valuable turkey lines in frozen form for future use. (NP 101)

Development and approval of the first African swine fever vaccine. African swine fever (ASF) is a devastating and highly lethal disease of pigs for which there were no commercial vaccines. ARS scientists at the Plum Island Animal Disease Center (PIADC) in New York successfully developed innovative genetic engineering techniques that enabled the discovery of a live attenuated vaccine that was shown to be fully protective and safe in experimental clinical studies at PIADC. The vaccine was subsequently transferred in June 2020 to the National Veterinary Joint Stock Company (NAVETCO) in Vietnam through a research agreement. ARS scientists working in partnership with NAVETCO successfully tested, in record time, the vaccine against locally circulating Vietnamese ASF virus field strains in pigs of European and Asian genetic background. NAVETCO also showed that the vaccine is genetically stable, remains attenuated, and has no toxicity when inoculated in domestic pigs. NAVETCO received a certificate of Marketing Authorization from the Vietnamese Department of Agriculture and Rural Development on June 3, 2022, making this the first ASFV vaccine ever approved for commercial use. The vaccine is currently being deployed under controlled field conditions in swine farms in Vietnam to further evaluate its safety and efficacy characteristics. If successful, Vietnamese authorities will develop plans to integrate ASF vaccination in their National ASF Control Program. (NP 103)

Beef composite breed composition not stable over time. Composite cattle breeds are commonly used in the U.S. beef industry to combine individual pure breed strengths and benefit from the hybrid vigor obtained by crossing divergent genetics. In statistical theory and classic quantitative genetics, composite breeds under no selection pressure are thought to maintain consistent breed composition percentages from generation to generation that follow initial breed development. Genomic tools and technological advances now make lineage tracing and breed composition estimation more powerful. ARS scientists in Miles City, Montana, and Fort Collins, Colorado, evaluated genomic breed composition over time in an ARS three-breed composite formed in the 1980s and their results indicate that the current genetic composition changed substantially from quantitative estimates. These changes show that original breed proportions are not stable over generations: environment and management, independent of artificial selection, influence the alleles that remain over extended periods of time, and favorable alleles originating from the most environmentally adaptive breeds increase in frequency. This finding suggests there is an opportunity to identify genetic types that are more fit for a given environment and supports application of genetic by environment by management principles in U.S. beef cattle production. (NP 101)

Advancing Sustainable Aquaculture Production

The ARS aquaculture research program is assessing new technologies and more cost-effective solutions for a variety of aquaculture problems. Meeting the seafood demands of a growing global population also requires minimizing the impact of sustainable aquaculture production on natural resources. ARS scientists are creating strategies such as vision systems that are improving aquaculture farm health and methods for determining fish population biomass to eliminate fish stress, which supports sustainable domestic aquaculture production. The following accomplishments in 2022 highlight ARS advancements in real-time fish monitoring, disease prevention, and breeding selection.

Precision aquaculture technologies for recirculating systems. Although precision agriculture technologies have not been widely applied to U.S. aquaculture, they could eliminate fish stress associated with the traditional, hands-on methods for estimating population biomass. ARS-funded scientists in Shepherdstown, West Virginia, developed an artificial intelligence (AI)-aided computer vision system for real-time fish monitoring of fish size and numbers in recirculating aquaculture systems. Underwater

images and videos were acquired to train an AI fish detection model, and the developed vision system detected whole and partial fish in the field of view with more than 85 percent precision. These findings demonstrate the capability for precision technology to assist non-invasive fish condition monitoring and biomass estimation, benefiting fish health, welfare, and production efficiency. (NP 106)

Marker-assisted selection for resistance to bacterial cold-water disease. Bacterial cold-water disease (BCWD) is one of the most devastating diseases in rainbow trout aquaculture. Improving resistance to BCWD using traditional family-based selective breeding or genomic selection with markers spanning the entire genome is promising but limited because these methods are labor intensive and costly, and the resistance trait cannot be measured directly in potential breeders. For these reasons, marker-assisted selection is advantageous because it can directly and relatively inexpensively predict the genetic merit of potential breeding animals using a small number of DNA markers. ARS researchers in Leetown, West Virginia, identified a set of six DNA markers that can be used to predict the genetic merit of breeding animals as accurately or even more accurately than traditional family-based selective breeding approaches for genomic selection. Using these markers is simpler and less expensive, and the effectiveness of this approach was demonstrated in a commercial breeding population, indicating that it can further improve the efficiency and sustainability of rainbow trout aquaculture in the United States. (NP 106)

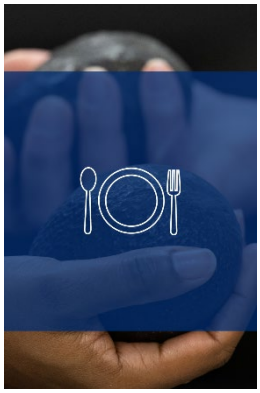
New strategy for controlling snails. Trematode infestations on catfish farms have been linked to significant production losses and farm closures. Trematodes were initially recognized as an emerging pest in the late 1990s, and management strategies targeted the trematode life cycle by eradicating the snail intermediate host in the pond environment. Copper sulfate is the most widely used treatment option and is highly effective against snails with a single application of 3 ppm, but this treatment level can result in increased mortality in fish, especially when water temperatures are elevated. ARS researchers in Stoneville, Mississippi, and Mississippi State University researchers demonstrated that weekly low-dose copper treatments (1.0-1.5 ppm) spread across 4 weeks are as effective in killing snails and treatment rates <0.1 ppm can halt snail reproduction and kill snail embryos. This approach is being combined with a new delivery system to better manage snail populations and reduce trematode populations in catfish ponds. The system utilizes a radar groundspeed sensor and a logic-based control system to distribute granular copper sulfate evenly and accurately along the pond margins in a single pass. (NP 106)

Development of an effective oral enteric septicemia of catfish vaccination platform. Enteric septicemia of catfish is considered the most problematic bacterial disease affecting catfish fingerling production. Historically, management strategies relied on using medicated feed and feed restrictions to limit the oral infection routes. While both strategies can be effective, the overuse of medicated feeds results in the development of antibiotic resistance, rendering the medication useless, and feed restrictions severely limit growth. In efforts to develop more proactive management strategies, ARS researchers in Stoneville, Mississippi, developed a live attenuated vaccine and a mechanized delivery system enabling in-pond vaccination during the early stages of fingerling production. The oral vaccine is currently available by veterinarian prescription and has dramatically increased survival and profitability of fingerling catfish production. Currently, more than 90 percent of catfish produced in Mississippi and Alabama are vaccinated with the delivery platform, which is applicable to other live attenuated vaccines as well. The vaccine also provides cross protection against *Edwardsiella piscicida*, an emerging pathogen in hybrid catfish production. (NP 106)

Who ARS Serves: Consumers, Farmers, Communities, and Research Partners

ARS research geneticist Arian Avalos and other researchers have identified a particular region in gentle Africanized honey bee genome that contributes to reduced colony defensive behavior. USDA Media by Lance Cheung.

Advancing Human Nutrition Research



The ARS human nutrition research program prioritizes the development of health-promoting diet choices based on scientific evidence to improve U.S. public health. Principal components of the human nutrition research program include linking agricultural practices and beneficial health outcomes; monitoring food composition and nutrient intake; ensuring the scientific basis for dietary guidance; preventing obesity and obesity-related diseases; and life-stage nutrition and metabolism (understanding how nutrition promotes health from conception to old age). Without developments in dietary guidance to prevent disease and other health issues, vulnerable populations are at risk. ARS scientists support human health at all stages by researching gut bacteria and microbiomes for improved gut health as well as analyzing data to better understand relationships between nutrient intake, eating patterns, and health conditions. The following accomplishments highlight ARS advances human nutrition research in 2022.

Maternal weight affects some human milk amino acids influencing infant growth. To better understand how excessive maternal weight changes human milk composition, cooperative researchers in Little Rock, Arkansas, investigated how the branched-chain amino acid content in human milk differed between mothers of normal weight and overweight or obese mothers. They found that the amino acid content differed in milk from the two groups and that infant consumption of these branched-chain amino acids was associated with growth and body composition. (NP 107)

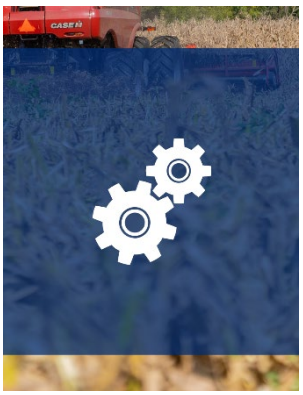
Release of national dietary survey data - What We Eat in America, NHANES 2017-March 2020. Monitoring dietary intakes is critical to understand nutrition's implication to health and the well-being of the U.S. population. New nationwide dietary intake data collected in What We Eat in America (WWEIA) for 2017-March 2020 were released on the web for public use. The data include information on the dietary intakes of more than 12,600 individuals on 2 nonconsecutive 24-hour days, and sample weights that can be used to make estimates about dietary intakes of the U.S. population. Select reported results show that 1) two out of three adults are late evening eaters (after 8:00 p.m.), and were most likely to consume sweets, sandwiches, and beverages; 2) one out of four adults consume food items from convenience stores on any given day, accounting for nearly 20 percent of daily energy intake for people who reported convenience store purchases; and 3) more than one in three individuals consume a savory snack food such as chips, flavored snacks, popcorn, or pretzels on any given day. Linked with health indicators from other components of the NHANES, these data provide stakeholders critical measures to study relationships between nutrient intake, eating patterns, and health conditions. The data and 39 summarized data tables are accessible from www.ars.usda.gov/nea/bhnrc/fsrg. (NP 107)

Dietary sugars and bacteria in the gut contribute to abdominal pain and obesity. Sugars in the human diet can impact the types and function of gut bacteria, which in turn can modify hormones that might play a role in the development of obesity. Researchers at the Children's Nutrition Research Center in Houston, Texas, administered two types of sugars (one easily absorbed, and another not easily absorbed) to children with irritable bowel syndrome, a common condition in children and adults that causes abdominal pain and changes in stool habits. Children who developed abdominal pain in response to the poorly absorbed sugar had a greater abundance of a hormone associated with obesity. These results highlight the way diet and gut bacteria interact to cause abdominal pain. In addition, the results show that the types and abundance of certain bacteria can affect hormones and potentially contribute to the development of obesity. Based on this research, future studies might help guide the development of diets and treatments that could result in gut bacterial populations that do not prompt pain or increase the likelihood of obesity. (NP 107)

More diverse gut microbiomes co-occur with diverse sources of carbohydrates. A high-fiber diet has strong associations with better health, probably because of fermentation products produced by the bacteria in the human colon or individual physiological differences. However, many types of fiber interact

uniquely with gut bacteria and current food databases do not adequately describe these various dietary fiber types. ARS researchers in Davis, California, assembled data from 343 healthy U.S. adults on their consumption of fiber-containing foods into a tree structure describing their relatedness to capture the diversity of fiber types found in the diet. The variety of fiber-containing foods consumed was strongly associated with the diversity of the gut bacterial community. These results suggest that current dietary guidance, which recommends higher fiber intake but does not address fiber types, should also consider fiber diversity as an approach to improving health for Americans. (NP 107)

Reducing Labor and Advancing Precision Agriculture Through Automation



ARS labor-saving tools and technologies continue to improve crop and livestock water management efficiency. The fundamental and applied research on the processes that control water availability and quality is a priority for the health and economic vitality of the American people. ARS is providing decision support tools such as real-time weather and reservoir monitoring sensors and using forecasting techniques to advance the conservation and preservation of natural resources. ARS research efforts are highlighted by the following accomplishments in 2022.

Cost-effective, real-time weather and reservoir monitoring sensors. ARS scientists in Stillwater, Oklahoma, collaborated with Virginia Tech scientists to develop low-cost weather and reservoir-monitoring sensor stations. These stations cost $250, while commercially available scientific grade weather stations cost approximately $30,000, so the new stations are 99 percent less expensive, presenting the opportunity to deploy 99 sensors for the previous cost of deploying one sensor. Scientists will be able to deploy sensor networks more densely for developing new and improved decision support tools, models, and ***applications*** for forecasting flooding and drought. These sensors provide data and information to a vast array of end users such as farmers, producers, emergency managers, dam owners, investors, and policy makers. This data and information can be accessed for irrigation scheduling, rural and municipal water supply allocations, emergency preparedness, dam operation and maintenance, and developing zoning regulations. (NP 211)

Snowmelt modeling technology to predict water availability in California. Drought and ongoing climate warming have greatly altered snow water supply in the mountainous western United States, requiring new approaches to water supply forecasting that explicitly account for variations in snow accumulation and melt. California receives most of its precipitation during the winter, and mountain snowmelt typically accounts for about one-third of the annual water used by California farms and cities. The California Department of Water Resources (CADWR) initiated a pilot program for incorporating the Automated Water Supply Model/iSnobal snow model developed by ARS researchers in Boise, Idaho, into their operational snow water supply forecasting infrastructure, and ARS researchers provided CADWR engineers with technical support and software troubleshooting. The modeling framework was successfully implemented in real time on CADWR computing resources, and the spatial snowmelt information was integrated into the CADWR operational forecast used to allocate limited water resources. This valuable tool enables CADWR water supply forecasters to readily incorporate complex physically based modeling to forecast reliable estimates of the amount and timing of available snowmelt, which is critical for ensuring sustained production across California. This greatly improves our ability to accurately monitor snow depth and water content, allowing us to better predict the volume and timing of spring and summer river flow and irrigation water availability. This also enhances early warning of drought or flooding and helps optimize planning for agricultural and urban water use. In the spring of 2023, the technology documented snowpacks in excess of 300 percent of normal in the Sierra Nevada Mountains, allowing

irrigation districts and dam managers to schedule controlled draw down in preparation for record runoff volume. (NP 211)

Groundwater transfer and injection for augmenting depleted aquifer. Using groundwater for irrigation has resulted in long-term declines in the Mississippi River Valley alluvial aquifer. The Groundwater Transfer and Injection Pilot project was constructed in Mississippi's Delta region to test the feasibility of withdrawing water near the Tallahatchie River, where it is filtered naturally by passing through sands adjacent to the river, and injecting the water into an area where the aquifer is depleted. ARS researchers in Oxford, Mississippi, studied groundwater levels and quality near the withdrawal and injection sites during short-term experiments and results showed that this technology can increase the amount of water in the aquifer under these regional conditions. Filtration of river water through the sandy sediments adjacent to the river improved its quality and pumping the water into the aquifer increased groundwater levels 1 to 7 feet within a radius of 1 mile from the injection wells. Regional stakeholders have expressed keen interest in this project and are considering the potential for applying this technology to support irrigated agriculture and sustain natural ecosystems. (NP 211)

BenchBot: A low-cost autonomous robot for high-throughput phenotyping and building image repositories. High-throughput phenotyping systems for greenhouses and semi-field conditions are critical for plant breeding and building image repositories that use computer vision and artificial intelligence for mapping cash crops, cover crops, and weeds. However, these high-throughput phenotyping systems are costly, resulting in limited use. ARS scientists in Beltsville, Maryland, designed and built BenchBot, a fully autonomous robotic platform, in collaboration with North Carolina State University researchers. BenchBot costs less than $20,000, significantly less than most commercial and research grade systems that cost millions of dollars. Designs for BenchBot are published on GitHub and are being used for high-throughput phenotyping by ARS, North Carolina State University, and Texas A&M scientists for building a national agronomic plant image repository. BenchBot is a low-cost, user-friendly technology that is making high-throughput phenotyping accessible for researchers. (NP 304)

Improving Rural Economies Through New Uses of Agriculturally-Based Materials

ARS research enhances the competitiveness of U.S. agriculture by improving the quality and marketability of harvested foods and agricultural feedstocks. The development of new agriculturally based materials is beneficial to farmers, consumers, and retailers because the products are environmentally friendly, support more diverse crop markets, and enhance economic opportunities for rural communities The following accomplishments in 2022 are examples of how ARS researchers develop these products.

Environmentally friendly bioplastic from dairy waste. Agro-based materials are increasingly used to replace petroleum-based feedstocks because they are sustainable, eco-friendly, easier to recycle, and non-toxic. ARS researchers in Peoria, Illinois, utilized a sugar called lactose, which is a cheap and widely available byproduct of cheesemaking and casein production, to make polyurethanes via a newly developed green microwave process that eliminates the standard industry use of toxic catalysts needed to accelerate reaction. This microwave procedure was found to reduce the reaction time and save energy relative to conventional heating, and the lactose-based polyurethane can be mixed with additional polymers to generate different plastics. These bioplastics are suitable for biomedical applications and for replacing polymers made from petroleum-based materials and can generate added revenue for the dairy industry. (NP 306)

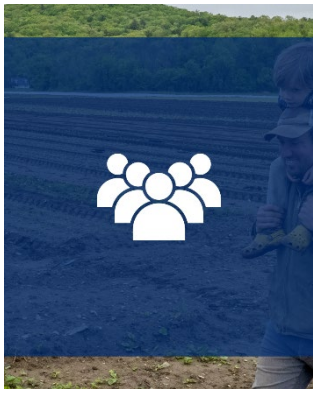
Hemp seed oil-based margarine for health-conscious consumers. Cold-pressed hemp seed oil (HSO) is known to have many bioactive phytochemicals that promote human health and is low in saturated fats.

ARS researchers in Peoria, Illinois, used their oleogel technology—a process where semi-solid fat or oil replaces unhealthy solid fats and is combined with natural waxes to make margarine—to create a HSO-based oleogel. When compared with commercial grade margarine spreads for hardness, HSO oleogel was achieved with less than 3 percent wax, whereas hardness for commercial stick margarines required up to 7 percent wax. This information is important for food companies seeking a way to develop healthier spreads that incorporate oils with low levels of saturated fats and healthful bioactive components. Margarines based on HSO will be highly desirable for health-conscious Americans. MARS Inc. and ParagonPure have expressed interest in this technology. (NP 306)

Improved fermentation of unrefined biomass sugars into biofuels. Unrefined sugars extracted from agricultural residues are difficult for industry to process into biofuels because they contain other chemicals that inhibit fermentation. One of the most problematic of these is acetic acid, because it persists throughout fermentation, dramatically lowers production even at modest concentrations, and is expensive to remove using current technologies. ARS researchers in Peoria, Illinois, developed a process to conveniently remove acetate and other chemical inhibitors that does not require additional equipment, compared to other detoxification methods. The heart of the process is the fungus *Coniochaeta ligniaria*, which is especially good at growing on acetate. The process was also successful for fermenting sugars prepared from acid treated biomass such as rice hulls, which are notoriously difficult to ferment because of their high acetate content. Fermentation of biomass treated with this fungus resulted in high biofuel yields. While this new fermentation process is of interest to rice farmers looking for a new market for their hulls, it also directly benefits all agricultural processors interested in biofuel production. Several universities recently received NIFA funding to apply this research to regional biomass feedstocks. (NP 306)

Catfish bone powder increases the appeal of fried catfish strips. Catfish bones or frames are a waste product of the filleting process. ARS scientists in New Orleans, Louisiana, and Louisiana State University colleagues transformed catfish frames into a high calcium, safe-to-eat bone powder and incorporated it into breading mixes. Fried catfish strips coated with bone powder mixes generated positive feedback and favorable acceptance from consumers, and information about bone powder utilization increased consumer interest in product purchases. Using this catfish byproduct in prepared foods can reduce waste from the aquaculture sector, enhance value for producers, and increase calcium in foods without hindering sensory quality.(NP 306)

Expanding Public Access to Agricultural Information



ARS strives to supply publicly available data and local, regional, and national tools and information that support American taxpayers. Providing accurate and user-friendly agricultural data that is available for land managers, farmers, and ranchers is valuable to enhance profitability for all stakeholders. ARS is continuing to develop databases such as the collection of gridded temperature data, which is used to determine county-level freeze/frost trends, to help minimize crop losses. Expanding access to digitized agricultural data and resources enables the public to further utilize ARS research and assists non-traditional stakeholders such as homeowners. The following milestones in 2022 demonstrate how ARS research supports fact-based, data-driven decision-making.

Regional freeze date trend tool for important cropping decisions. Specialty and row crop production are being severely affected by changing freeze dates and growing season length. Various measures of climate changes, including temperature, precipitation, and humidity data, exist regionally and nationally, but there were no measures for local updates about changes in last-spring and first-fall freeze dates. Previous maps from the 4th National Climate Assessment showed only season-length changes by multi-state regions.

ARS staff in Ames, Iowa, cooperated with the USDA Midwest Climate Hub and the Midwest Regional Climate Center at Purdue University to create a publicly available county-level freeze/frost date tool using gridded temperature data collected since 1950 to calculate and display trends in first fall and last spring freeze dates and growing season length. Specialty and row crop producers can use this information to improve crop management decisions in a changing climate and minimize crop losses and damage related to unseasonal frost events. (NP 216)

Development of a gold-standard, chromosome-scale reference genome of an octoploid strawberry. Molecular breeding and genetics research in strawberry (Fragaria x ananassa) was historically hampered by its complex genome, which contains eight complete sets of chromosomes within a single cell (humans have only two complete sets). This prevented the accurate design and development of subgenome-targeting molecular markers, underlying gene content and function analyses, and haplotype structure assessments, all of which are core aspects of modern plant genetics. An ARS researcher in Corvallis, Oregon, collaborated with the public strawberry breeding program at the University of California, Davis, in using cutting-edge sequencing and assembly tools to develop a new genome assembly of the strawberry cultivar 'UCD Royal Royce.' The assembly, called FaRR1, is greatly superior to previous octoploid genomes and represents the closest approximation of octoploid strawberry chromosomes as they exist in an actual plant cell nucleus to date. It is publicly available and has already been used for development of new molecular marker platforms to support public strawberry research. (NP 301)

Database development improves homeowner turfgrass selection. Since 1981, the National Turfgrass Evaluation Program (NTEP) has collected data on tens of thousands of experimental and commercially available turfgrasses, encompassing 20 species across multiple locations in the United States and Canada. As part of NTEP, ARS researchers in Beltsville, Maryland, assembled, reviewed, analyzed, and reported these data via media and the NTEP website, and a database was recently created to house and serve the nearly one million data records collected. Through a USDA Specialty Crop Research Initiative grant to develop low-input grasses, ARS and University of Minnesota collaborators added fanleaf fescue to the publicly available database in July 2022. Development of tablet and smartphone apps are underway and will enable homeowners to locate the best cultivar based on their location, soil type, tree canopy situation and other factors. (NP 215)

A powerful national soil health interpretation and recommendation tool. The adoption of soil health practices has been hampered in part by the lack of a scientifically robust and user-friendly interpretation tool. An ARS researcher in Columbia, Missouri, led a team of scientists from multiple other institutions in developing a framework called the Soil Health Assessment Protocol and Evaluation (SHAPE). This tool accounts for inherent site conditions, such as soil type and climate, and provides a soil health score for up to four soil health indicators at any location across the continental United States. Version 1.0 of SHAPE is complete and is publicly available online via GitHub and as a Shiny App. This research benefits producers and scientists by providing an improved soil health interpretation tool to monitor changes in soil health, provide management recommendations to landowners, and inform soil health programming efforts. (NP 212)

How ARS Does It: Prioritizing Animal, Human, Plant, and Environmental Health

Farm assistant George Kloph shows an large organic egg, right, and a large double yoke egg, left, that he discovered during his checks on the health and safety of laying hens at Nick's Organic Farm, in Adamstown, MD. USDA Photos by Lance Cheung.

Protecting Animal Health Through Disease Detection, Prevention, and Control

The ARS Animal Health research program protects and ensures the safety of the nation's agriculture and food supply through improved disease detection, prevention, and control. Solutions to mitigate virus exposure are necessary to improve animal health and prevent the spread of diseases. ARS researchers are developing diagnostics and mitigation strategies to detect, control, and eradicate animal diseases and health issues, such as by studying genetic variants to prevent congestive heart failure in bovines. The following accomplishments highlight some of the ARS advances in animal health research in 2022.

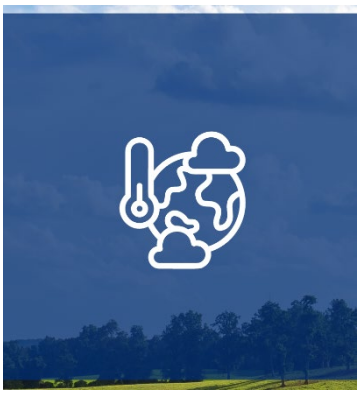
Genetic resilience to ovine progressive pneumonia. Ovine progressive pneumonia (OPP) is a progressive, incurable viral disease of sheep that can increase susceptibility to secondary diseases, ultimately resulting in millions of dollars of annual economic losses to the sheep industry from death and productivity losses. ARS researchers in Clay Center, Nebraska, used data from three long-term, multi-generational studies to evaluate how genotype combinations of the TMEM154 gene affect OPP infection status and ewe lifetime productivity. In a common environment, and with similar levels of natural virus exposure, fewer than 10 percent of ewes with the favorable genotype became infected with OPP through 5.5 years of age, but more than 80 percent of ewes with the unfavorable genotype were infected by 3.3 years of age. Ewes with the favorable genotype produced 2.1 more lambs and 40 kg greater total weight of weaned lambs over a 5-year period. Identifying the favorable TMEM154 allele combination and subsequent genetic selection will improve flock health and lifetime productivity, with an estimated economic impact of $171 per ewe in additional lifetime revenue. Producers are now able to capture this impact through testing and selection. (NP 101)

The placenta of sheep with atypical scrapie is not infectious. Scrapie is a disease of sheep caused by the accumulation of abnormal proteins, called prions, in the central nervous system. This disease has been almost completely eradicated in the United States because of concerted efforts to breed sheep with genetic markers associated with high resistance to the classical forms of naturally transmissible scrapie prions. Nor98-like scrapie is a sporadic, atypical form of scrapie thought to spontaneously arise in the central nervous system of aging sheep. ARS researchers in Pullman, Washington, confirmed that these atypical prion-like proteins accumulate in the placenta of scrapie-resistant sheep, but that the placental proteins are not infectious. This knowledge supports field evidence that Nor98-like scrapie is a spontaneous disease of sheep with low to no risk of natural transmission. Furthermore, this knowledge supports the continued use of selective breeding of scrapie resistant sheep to mitigate the occurrence of classical forms of scrapie in sheep. (NP 103)

Genetic variants associated with bovine congestive heart failure. Bovine congestive heart failure (BCHF) in feedlot cattle is increasingly common in North America's western Great Plains; reported losses in individual feedlot operations exceed $250,000 annually, which could represent 10-20 percent of a feedlot's income. While BCHF is an untreatable, complex, and fatal condition, cattle affected with BCHF are typically bred and managed to achieve high-quality carcasses, so reducing BCHF's impact is a priority for the beef industry. ARS researchers in Clay Center, Nebraska, evaluated animals with end-stage heart failure from 30 different ranch sources, together with their healthy pen mates. The researchers discovered DNA markers in two major genes that are likely to play a role in BCHF development. Feedlot animals that had these markers were 28-fold more likely to develop heart failure than those without the markers. These markers will serve as the basis for a genetic test that can identify feedlot animals at the highest risk for BCHF in North America's western Great Plains. In herds suffering from BCHF, identifying high and low risk cattle will enable producers to make informed decisions for selective breeding and animal health management to reduce the impact of this disease. (NP 103)

Tick identification using spectroscopic analysis of host feces. Ticks are blood-feeding parasites that vector pathogens of medical and veterinary importance and cause billions of dollars in economic losses globally each year. New methods for early detection of ticks, particularly exotic or invasive species, are needed; for instance, the timely detection of tick species on cattle hosts can mitigate the spread of devastating diseases like babesiosis and anaplasmosis. ARS researchers in Edinburg, Texas, and Texas A&M University collaborators found that Raman spectroscopy of infected host feces can be used as a non-invasive, non-destructive method to identify ticks. Further development of this surveillance method could lead to faster detection of exotic or invasive tick species or significantly reduce the time and cost of inspecting livestock as part of a tick management or eradication program. (NP 104)

Optimizing Agricultural Management to Mitigate Climate Change Impacts



The effects of climate change are making is increasingly challenging for land managers to make a living. To support these managers, ARS scientists are developing new management approaches and decision support tools to reduce agriculture's carbon footprint, build resilience, and boost farmer incomes. ARS climate research investigates opportunities to make plant and animal ecosystems more resilient to climate change and weather extremes and develops practices and technologies that offer new management techniques.

Targeted forages and additives reduce cattle enteric methane emissions. Reducing enteric methane emissions of dairy cows can lower their climate footprint, and diet formulation is targeted as one way to reduce methane. For grazing cows, one option is to grow high tannin forages in pastures, since tannins have several dietary benefits, including reduced enteric methane. However, tannins can interfere with cow digestion and reduce their productivity. Supplementing grazing diets with oilseed additives can counteract the negative tannin impacts and the oilseeds may themselves further reduce enteric methane due to their high lipid content. ARS scientists in University Park, Pennsylvania, used a lab-based fermenter system to evaluate how adding three oilseeds (soybean, sunflower, and canola), either alone or in combination, to a diet containing a high-tannin lespedeza forage affected methane emissions. Canola and sunflower led to 79 percent and 67 percent less methane than soybean, and the combined oilseeds led to 84 percent less methane than soybean. Soybean's lower lipid content was most likely the reason for its lowest effectiveness. Real-world challenges for implementing these diet options include the high cost and limited availability of canola and sunflower, and difficulty growing lespedeza in many environments. However, these results are adding to an expanding knowledge of dietary options for reducing methane from dairy cows and advance the development of options dairy producers can use to overcome these challenges. (NP 215)

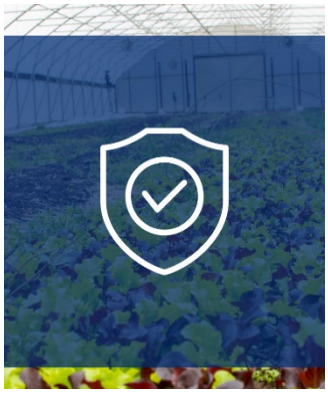
Climate change necessitates near-absolute weed control in corn and soybean. Estimates of future grain yields in the face of climate change assume weed-free conditions, but given the adaptability of weeds (e.g., the current epidemic in herbicide resistance), this assumption may not be realistic. ARS researchers in Urbana, Illinois, and university colleagues used a novel approach with existing herbicide evaluation trials conducted throughout 3 decades to identify the main drivers of yield loss in corn and soybean. Abnormally hot or dry conditions that were found during flowering—conditions expected to occur more frequently in much of the U.S. Corn Belt—exacerbated crop losses when weed control was less than absolute. As agriculture adapts to climate change, this research underscores the critical importance of developing more effective integrated weed management systems to help producers maximize yields and feed a growing population. (NP 304)

USDA-certified biobased personal care ingredients from renewable vegetable oils. New, economically viable, agri-based materials must be developed to sustain a bioeconomy that includes natural, renewable

products to replace petroleum-based products. For example, ultraviolet absorbents used in personal care products such as sunscreen are derived from petroleum-based products and are potentially associated with adverse environmental and health effects. ARS researchers in Peoria, Illinois, developed biobased methods to convert vegetable oils and compounds—which are found in all plants and are particularly abundant in corn and wheat bran—into products for the personal care market. The agri-based products recently earned the USDA Certified Biobased Product label and were shown to perform equally well, if not better, as their petroleum-based counterparts. These biobased commercial ultraviolet absorbents and antioxidants make up part of a $60 million market in the United States and European Union for personal care products made with natural ingredients, a market that is projected to grow 5 percent annually. This research created new and expanded market opportunities for agricultural commodities and combats climate change by reducing dependence on petroleum-based chemicals. (NP 306)

Controlling apple peel disorders linked to climate change. Increasing temperatures and sun exposure contribute substantially to apple peel disorders and postharvest loss and waste. ARS scientists in Wenatchee, Washington, and Washington State University collaborators developed a fruit sorting protocol that determines the risk of apples developing climate-related postharvest disorders. This protocol predicted the development of sunscald, a sun-related disorder that affects the highly sensitive 'Granny Smith' variety and many other commercially important apple cultivars, with a 95 percent accuracy rate even before symptoms developed. Adapting this system to existing commercial apple fruit sorting lines or in-field sorting lines essentially eliminates sun-related postharvest disorders and crop losses from the apple industry cold chains. This research received financial support from the Washington Tree Fruit Research Commission. (NP 306)

Safeguarding the Food Supply



Food safety research investigates options for assessing, controlling, or eliminating potentially harmful food contaminants, such as introduced and naturally occurring pathogenic bacteria, viruses, parasites, toxins, non-biological-based chemical contaminants, mycotoxins, and plant toxins. Food safety is a global issue; thus, the research program involves both national and international collaborations through formal and informal partnerships. Because poor food management and storage systems can cause widespread illnesses, it is necessary to study food production as an integrated system. For example, ARS is researching storage conditions in international egg transport and documenting farm location and salmonella prevalence to prevent the disease in pastured poultry. The following accomplishments highlight a few of the ARS advances in food safety and quality assurance in 2022.

Seasonality of E. coli O157:H7 survival and microbiome in cold-stored fresh-cut lettuce. Outbreaks of *Escherichia coli* O157:H7 (*E. coli* O157) foodborne illness linked to romaine lettuce grown on California's Central West Coast are more prevalent in the Fall season. The cause of this seasonal trend is unknown and is of critical concern to regulatory agencies, public health agencies, and the produce industry. These outbreaks have greatly impacted the California lettuce industry, which is valued at more than $2 billion annually. ARS researchers in Albany and Salinas, California, collaborated with FDA scientists and found two factors associated with the outbreaks: *E. coli* O157 survives better on cold-stored fresh-cut romaine harvested in the Fall rather than in the Spring, and the lettuce microbiome itself has seasonal characteristics. It is not clear how the seasonal properties of lettuce and/or its microbiome factor into the seasonal behavior of *E. coli* O157 in lettuce, but the results indicate that producers should be more cautious in the Fall season. These findings also open a new branch of study for identifying plant

traits and microbiome components that might be used in plant breeding or manipulated to suppress enhanced *E. coli* O157 survival. (NP 108)

A farm-to-fork perspective of Salmonella in pastured poultry management systems. Greater consumer demand for all-natural, antibiotic-free poultry products has led to an increase in pastured poultry operations. This, in turn, has increased the level of interactions poultry have with outdoor environments and potentially increased their exposure to foodborne pathogens. ARS researchers in Athens, Georgia, are researching the prevalence and diversity of Salmonella populations inherent within pastured poultry flocks. Salmonella was isolated and characterized from preharvest, postharvest, and final product samples obtained from flocks raised without antibiotics, and the bacterium was recovered from ~18 percent of more than 2,300 samples. Even in the antibiotic-free pastured management system, approximately two-thirds of the Salmonella isolates exhibited resistances to tetracycline, streptomycin, and other clinically important antibiotics. Salmonella prevalence and diversity were related more to farm location than to sample type, indicating the need for more tailored intervention strategies that continue to enhance the safety of these products. (NP 108)

How extended egg storage conditions affect egg microbial and quality factors. ARS scientists in Athens, Georgia, completed a 6-month study to determine the impact of egg handling practices and egg storage conditions on the microbial and physical quality of shell eggs. Egg practices included washing, washing and oiling, storing 21 days and then washing, and no washing, while storage included refrigerated and room temperature conditions. For the first time, typical egg handling practices used throughout the world were compared over a prolonged period of egg storage at both refrigerated and room temperatures, and results indicated that refrigeration has a greater impact on the microbial and physical quality of eggs than egg handling practices. These results provide a complete and direct comparison of egg handling and storage practices that can be utilized internationally when assessing egg import and export standards. (NP 108)

Elucidating the origin and diversity of fungi causing tar spot disease of corn. The fungal pathogen Phyllachora maydis causes the disease tar spot on corn, which has recently emerged as a major threat to U.S. corn production's $53 billion annual farmgate value. The origin of this disease is still unclear, and there might be multiple pathogens causing the disease. An ARS researcher in Peoria, Illinois, collaborated with researchers at the University of Illinois and several other U.S. universities to sample tar spot disease from across Central America, North America, and South America (including the Caribbean) to understand the origin and diversity of the pathogen causing tar spot disease. DNA data analyses determined there are three species of Phyllachora that cause tar spot of corn in the United States. It is likely these three species originated in Mexico, Central America, and the Caribbean. These results indicate the pathogens are native to North America and the emergence of the disease is likely due to a combination of climate changes that favored the spread of the fungus in U.S. corn production regions and a shift in corn genetics that resulted in a lack of resistance to the three Phyllachora species that cause this disease. These results can assist corn breeders, pathologists, agronomists, and corn growers as they try to better understand the biology of this fungus and develop resistant varieties and crop management strategies to reduce yield losses. (NP 301)

Protecting Human and Animal Health by Mitigating the Spread of Viruses

ARS research informs and provides solutions to improve the U.S. biodefense response, which is a cross-cutting issue for both agriculture and public health. USDA defines biodefense as "the prevention, detection, and response to deliberate or accidental release of biological agents that could cause harm to people, animals, or plants." The risk of disease introduction—whether natural, intentional, or accidental—is increasing due to climate change and the increased movement of animals, plants, arthropods, and people around the globe. These diseases are a threat to food security and to human, animal, and environmental health. U.S. biodefense as a safe and inexpensive tactic is compatible with integrated pest management approaches to ensure food security, economic, and food system resilience. The following accomplishments in 2022 highlight multidisciplinary efforts across ARS to use biodefense tactics focused on prevention, detection, response, and recovery.

Cotton textile-based sensor to detect and trap SARS-CoV-2 virus. Combatting the virus that caused the COVID-19 pandemic has been challenging for healthcare professionals and the public. ARS researchers in New Orleans, Louisiana, investigated how cotton can be used to both detect and prevent virus infections. They enhanced natural cotton peptides to resemble human cell peptides and demonstrated that the shape of the peptides influences their ability to adhere to the virus; they also found that the cotton peptide increased its ability to bind with the virus as the negative charge of the peptides increased. This finding, which helped in designing protective cotton textiles, might also be used in developing textiles to detect, trap, and neutralize viruses and designing personal protective equipment. It could also influence the development of control measures for the current and future pandemics. (NP 306)

Humans infected with Rift Valley fever could create global risks to public health and livestock. Rift Valley fever virus (RVFV) is a zoonotic virus that is transmitted by mosquitoes and causes Rift Valley fever (RVF), which primarily affects domestic ungulate livestock and humans. Outbreaks of RVF in its native range of Africa and the Arabian Peninsula cause pronounced human and animal health and economic impacts. Scientists in Gainesville, Florida, in partnership with NASA-Goddard Space Flight Center, conducted the first comprehensive review of risks that humans infected with RVFV could introduce the virus from endemic areas to non-endemic regions, and the potential spread of RVFV resulting from those introductions. This survey revealed that humans infected with RVFV and capable of infecting mosquitoes have arrived in non-endemic regions repeatedly and present a serious risk of allowing the virus to spill back into wild and domestic ungulate livestock populations, which could enable the virus to become endemic in North America, Europe, and other continents. The report generated from this survey provided detailed, tractable processes to develop monitoring systems to protect public health and livestock economies in these areas. (NP 104)

White-tailed deer are susceptible to SARS-CoV-2, but cattle, poultry, and swine are not. It is likely that the COVID-19 pandemic caused by the SARS-CoV-2 virus originated in bats and passed through an unknown animal host before its transmission to humans. At the start of the COVID-19 pandemic, ARS scientists performed emergency response, high-priority research to determine the susceptibility of various livestock species to infection with the SARS-CoV-2 virus. Their results indicated that cattle, swine, chickens, turkeys, ducks, quail, and geese were not susceptible to SARS-CoV-2. However, white-tailed deer were highly susceptible; they did not demonstrate clinical symptoms but did shed large amounts of virus in the first 5-6 days after infection, and readily transmitted the virus to other deer. APHIS Wildlife Services then initiated surveys of SARS-CoV-2 in wild white-tailed deer and found it was possible for deer to act as a reservoir for the virus and transmit it to humans. ARS scientists also demonstrated that farmed mink are susceptible to SARS-CoV-2 infection and viral shedding, despite not exhibiting symptoms. This information is critical for consumers, scientists, livestock producers, and regulatory officials who have public health responsibilities. (NP 103)

Handheld fluorescence imaging device for surface contamination detection and disinfection. Cleaning and sanitizing are important steps to help prevent the spread of illness and disease, and both are critical components of USDA and FDA Hazard Analysis Critical Control Point (HACCP) regulation and management systems for food safety. Contamination inspection is currently conducted by human inspectors via either visual examination or spot-check testing, a process that limits productivity and is prone to error. Based on an ARS patented technology, a commercial contamination, sanitization inspection and disinfection (CSI-D) handheld imaging device has been developed for identifying and preventing contamination in food preparation and serving facilities. In testing, the system achieved one hundred percent sterilization for three different selected pathogens (the fungus *Aspergillus fumigatus*, the bacterium *Streptococcus pneumonia*, and the virus Influenza A) in under 10 seconds. When implemented, the commercialized CSI-D device will help improve efficacies for FSIS and the food processing industry for HACCP contamination and sanitation inspections required under the Food and Drug Administration Food Safety and Modernization Act. (NP# 108)

Combatting Antimicrobial Resistance

Antimicrobial resistance (AMR) occurs when microorganisms, such as bacteria, viruses, fungi, and parasites, change over time and no longer respond to medicines. This can make infections harder to treat and increase the risk of disease spread, severe illness, and death. AMR is a global health threat. The World Bank estimates that AMR could cause ten million deaths annually by 2050 and cost the global economy up to $100 trillion. ARS has a unique role in identifying AMR in animal, plant, environmental, and foodborne pathogens. ARS researchers study the ecology of AMR in agricultural and natural systems; the susceptibility of foodborne pathogens to biocides such as preservatives and disinfectants; and antibiotics critical to human medicine. ARS research efforts include developing ways to prevent agrochemicals from negatively affecting soil systems and assessing poultry immune responses to microbiologically safe products. The following 2022 accomplishments highlight ARS advances in optimizing the use of and reducing the need for antibiotics in agriculture.

Iron and biochar interaction increases chemical sorption capacity of biochar. Antibiotic chemicals are increasingly being detected in the environment. ARS researchers in St. Paul, Minnesota, examined the potential use of biochar to reduce the presence and availability of antibiotics in agricultural soils, as well as simple biochar pretreatments with iron salt solutions to increase biochar's effectiveness in removing antibiotics. Modifying the biochar with an iron-salt solution nearly doubled the increase in the observed antibiotic sorption capacity of the biochar. They also found that adding the iron-treated biochar to the soil system increased retention of antibiotics in the system by more than 2 days, thus reducing the amount of antibiotics entering the ground water supply. This information provides guidance for using biochar to mitigate antibiotics and other agrochemicals in the soil system. (NP 211)

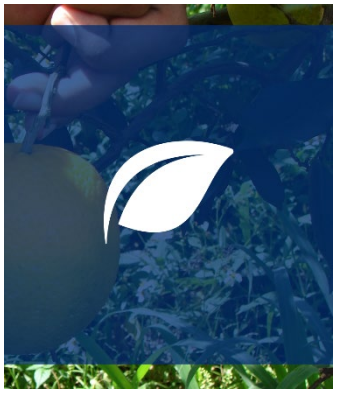
Nutritional mediated induction of immunity in breeder hens increases immune protection in chicks. Young chicks are susceptible to many different pathogens, including Salmonella, during the first week after hatch. Salmonella colonizes the intestinal tract of young poultry and is one of the leading causes of human foodborne illness. As poultry producers move away from routine antibiotic use, there is a growing need to identify alternative approaches to protect and boost the natural immune responsiveness of newly hatched chicks. ARS researchers in College Station, Texas, working closely with industry and academic partners, showed it was possible to confer transgenerational protection against Salmonella colonization in young chicks by feeding the parent hens a diet supplemented with a blend of natural botanicals. They demonstrated that hens consuming a natural antibiotic alternative could produce chicks with a more robust immune response and that are more resistant to colonization by Salmonella. The work represents a

significant contribution to the goal of providing U.S. consumers with poultry products that are microbiologically safe. (NP 108)

NARMS framework for isolating and monitoring AMR Salmonella enterica from surface water. The National Antimicrobial Resistance Monitoring System Environmental Working Group (NARMS EWG) was established and tasked with developing a science-based, statistically valid framework for NARMS surface water monitoring of AMR enteric bacteria. A framework for the program was established and methods optimized for the recovery and isolation of antibiotic-resistant Salmonella. ARS researchers in Beltsville, Maryland; Riverside, California; Athens, Georgia; Maricopa, Arizona; and Clay Center and Lincoln, Nebraska, led collaborations with EPA and FDA partners to optimize program design and to refine and improve four different protocols for recovering Salmonella from surface water. Protocols were shared with all members of the NARMS EWG and made publicly available on protocols.io. As a result of ARS input, a robust scientific approach to better understand the contributions and persistence of bacterial AMR in U.S. surface water was developed and is being implemented and coordinated across the United States by these Federal agencies. (NP 108)

Antibacterial activity and stability of a new antimicrobial peptide. The increasing prevalence of antibiotic resistance among pathogenic microbes highlights the urgent need for the identification and development of alternatives to antibiotics. Antimicrobial peptides (AMPs) are highly effective against microbial pathogens that cause diseases in humans and animals, but they are sensitive to proteases and kidney clearance. ARS scientists in Ames, Iowa, developed a stable peptide and tested it for resistance against degradation, stability, toxicity, and in vitro and in vivo antibacterial activities against *Histophilus somni*, a bacterium causing respiratory diseases in cattle. The peptide was able to kill *H. somni* very efficiently. These results demonstrate the possible use of an alternative treatment for controlling bacteria that cause respiratory diseases in cattle. (NP 103)

Combatting Citrus Greening Disease



Citrus greening disease, also known as Huanglongbing (HLB), is a bacterial disease that affects citrus trees. The Asian citrus psyllid, a small insect that feeds on the sap of citrus trees, spreads HLB. The bacterium interferes with the tree's ability to transport nutrients, causing the tree to produce misshapen, bitter fruit and eventually die. HLB was first detected in Florida in 2005. Since then, it has spread to all commercial citrus-producing states in the United States, including California, Arizona, and Texas. The disease has devastated the U.S. citrus industry and caused a sharp decline in production and exports; in Florida alone, orange production has fallen by more than 50 percent since HLB was first detected. ARS is fighting HLB's spread with disease detection, prevention, and mitigation research. ARS research efforts are focused on studying how pests and preservatives affect the sustainability of citrus farming and on conducting research on Asian citrus psyllid behavior and breeding patterns to prevent and control the spread of HLB. The following ARS advancements in 2022 highlight ongoing HLB control efforts.

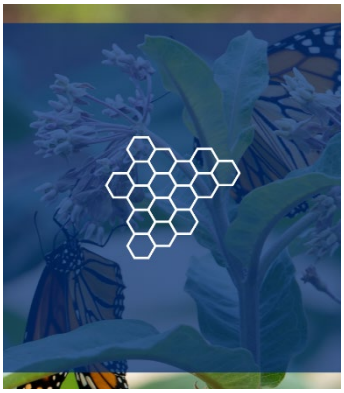
Deep learning algorithms improve detection of the Asian citrus psyllid. Early detection of the Asian citrus psyllid on young trees and in orchards can facilitate tree protection and targeted control efforts. ARS scientists in Gainesville, Florida, used deep learning methods to identify and characterize differences between male and female psyllid courtship calls. In addition to providing a method to differentiate males and females in infestations, this data has potential for the development of vibration-based control methods of mating disruption. Such a behavior-based control approach can help reduce pesticide use for managing the psyllid. (NP 304)

New method for tracking the citrus greening pathogen in single insects. The disease comes from plant infection by the bacterium CLas, which is acquired by the Asian citrus psyllid when it feeds on infected citrus trees and then transmits the pathogen to other trees. ARS scientists in Ithaca, New York, developed a method to enrich CLas cells from single psyllid insects for direct genome sequencing. The data generated allowed assembly of CLas genomes from single insects and the identification of differences in CLas DNA sequences that permits strain identification. This method allowed for tracking the strain of CLas from a single insect, which might help trace the origin of new outbreaks. (NP 304)

Plant symbiont systems deliver crop protectants. A major challenge in plant disease control is delivering protectants to the plant vascular system to control pathogens and the insects that transmit them via feeding on plant vessels. A plant symbiont-based system (SymbiontTM) developed by ARS researchers promises to be a cost-effective method for delivering biological therapeutic molecules that control citrus greening disease (Huanglongbing, or HLB) devastating the citrus industry in Florida. Traditionally, scientists use Agrobacterium, a common bacterium, to modify plant genes to generate transgenic plants that enable farmers to protect their crops against harmful insect pests and pathogens. However, transgenic plant adoption in agriculture has been limited, largely due to concerns over potential environmental impacts and the cost and time associated with environmental impact studies needed for regulatory approval of transgenic crops. ARS researchers in Fort Pierce, Florida, and Ithaca, New York, worked with a small Florida agribusiness to develop a method that, for the first time, used Agrobacterium to engineer independently growing plant cells, referred to as 'Symbionts', to produce molecules that can modify plant traits. When transplanted onto a plant, these engineered symbionts provide real-time delivery of desirable plant traits, eliminating the need to make the plant transgenic. Their results demonstrated that symbionts on citrus trees lasted more than 2 years without producing harmful effects to the trees, and improved symbiont transplantation and inoculation methods to produce more uniform and rapid growing symbionts. The results show that the Symbiont system has potential to efficiently deliver therapeutic molecules to the difficult-to-reach vascular system where it is needed most for controlling vectored plant diseases. (NP# 304)

Improved regulatory sampling for HLB infection. HLB infection has been found in urban settings in southern California and the first line of defense to control the spread of HLB is to eradicate infected trees. ARS researchers in Parlier, California, working with the California Department of Food and Agriculture and Central California Tristeza Eradication Agency, improved CLas detection by sampling the stems that support the flower or fruit and using real-time polymerase chain reaction for consistent isolation and detection of CLas DNA. Improving CLas detection and rapid eradication of infected trees reduces CLas spread. (NP 303)

Protecting Pollinator Health



Honeybees are important pollinators, and in the United States, honeybees pollinate more than $15 billion worth of crops each year, including fruits, vegetables, nuts, and seeds. Pollination by honeybees and other pollinators can increase yields, improve fruit quality, reduce the need for pesticides, and help prevent the spread of plant diseases. The decline of honeybee populations is a serious threat to food production. There are a number of factors that are contributing to the decline of honeybees, including habitat loss, pesticide use, and climate change. ARS researchers across the country are evaluating the ecology, distribution, conservation, and effectiveness of insect predators, pollinators, and other beneficial insects. They are also developing alternative honeybee nutritional resources that act as probiotics for the gut microbiome and serve as edible vaccines that boost the honeybee immune system to combat viruses. The following accomplishments in 2022 highlight ARS advances in pollinator health.

New supplemental honeybee diets include algae-based diets. Honeybee colonies managed for agricultural pollination are highly dependent on human inputs, especially for disease control and supplemental nutrition. ARS researchers in Baton Rouge, Louisiana, conducted a large-scale field experiment in collaboration with a commercial beekeeper and showed that the amino acid ratios in various artificial feeds were correlated to honeybee colony performance. This will help inform the industry regarding the need for the development of improved bee feed. They also collaborated with scientists at the University of North Carolina-Greensboro and found that novel microalgae-based artificial diets developed at the Baton Rouge location improved individual honeybee growth and health characteristics. The ARS researchers used bioengineering technologies to develop these microalgae strains to stimulate honeybee immune systems, which effectively enabled the microalgae to function as an edible vaccine (patent pending) that improves resistance to Deformed Wing Virus, a major pathogen responsible for honeybee losses worldwide. Producing these new microalgae strains is scalable to meet the capacity needs of the beekeeping industry, and they can be incorporated into supplemental feed to improve resistance against current and emerging pathogens in managed pollinators. (NP 305)

The source of microbes and pollen is key for bee larval development. Native bee species are a critical component of cranberry production, and bee larvae require microbes to complete their development. ARS researchers in Madison, Wisconsin, showed that the mother bee supplies larvae with a blend of microbes and pollen that is partially derived from her own brood cell and partially derived from the flowers she visits, all of which tend to be conducive to larval growth. To demonstrate the critical importance of this particular microbial seeding, microbes from a different species were substituted as the source of microbes and pollen. Despite having ample pollen and microbes, the fitness of bee larvae that consumed the substitute pollen and microbes declined significantly. This is the first evidence that bees require a particular microbial community and pollen community in their diet, underscoring the importance of microbes for supporting pollinator health. (NP 305)

Two major honeybee probiotics have no long-term effect or efficacy for antibiotic recovery. Antibiotic treatments can greatly distort the honeybee gut microbiome, reducing its protective abilities and facilitating the growth of antibiotic resistant pathogens. Commercial beekeepers regularly apply antibiotics to combat bacterial infections and often use probiotics advertised to ease the impact of antibiotic-induced imbalances in gut microbiota that contribute to poor health (dysbiosis). ARS researchers in Tucson, Arizona, performed a large longitudinal study of commercial honeybee colonies during winter to explore the effects of probiotics and antibiotics. The researchers found the gut microbiome or disease incidence was not affected by probiotic applications or probiotic treatments associated with antibiotic recovery. These results demonstrated the lack of probiotic effect for antibiotic rescue, detailed the dysbiotic states resulting from different antibiotics, and highlighted the importance of the gut microbiome for honeybee health. (NP 305)

Development of novel bee medicines. Various challenges currently facing honeybees and diseases caused by pathogens pose a significant threat to the health and well-being of honeybees. The development of antibiotic-resistant microbes make an already dire situation even worse, so new therapeutic interventions are urgently needed for safe and effective treatments. ARS scientists in Beltsville, Maryland, screened 50 natural products from plants and provided evidence that several compounds, including those commonly found in the pollens and nectars of plants that often attract honeybees, could lead to a significant improvement in immune function and significantly reduce virus levels in bees. These natural products provide a rich source of candidate treatments for bee and hive health. One plant compound, methyl jasmonate, was approved for patenting as a control measure for viral disease. (NP 305)

Optimizing Agricultural Water Use and Management

Agriculture is the largest user of water in the United States, accounting for about 70 percent of all freshwater withdrawals, and producers use water to irrigate crops, water livestock, and produce food. However, the United States is experiencing more droughts and water shortages, and in some areas, reservoir water levels have fallen to record lows, forcing water agencies to cut back on water deliveries to famers, leading to crop losses and financial hardships. To ease these water competition challenges, ARS is developing innovative water conservation practices, improving irrigation efficacy, identifying more water and location-efficient crops, incorporating conservation tillage, and documenting water conservation practices. The following accomplishments in 2022 highlight ARS advancements in irrigation technology and decision support systems to address these challenges.

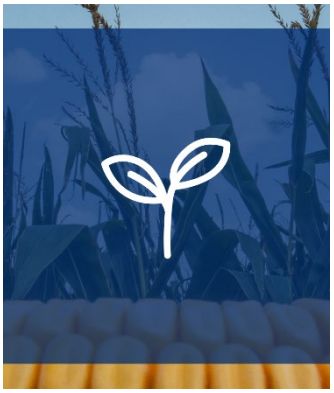
New cost-effective approach determines silage quality. Analyzing harvested silages for organic acids is critical for assessing silage quality for its value as an animal feed and spoilage risk during storage, but traditional approaches for analyzing silage can be expensive and time consuming. ARS researchers in Madison, Wisconsin, demonstrated that the quantity of silage organic acids can be predicted mathematically by their interactions with visible and near-infrared light wavelengths. This new approach is a low-cost, high-throughput method for rapidly characterizing silage water extracts and can benefit the silage research community by substantially reducing the cost of analysis and increasing throughput. Further development could allow cost-effective, on-farm silage quality diagnostics that save producers money and enable real-time decision-making, including identifying potential forage spoilage and avoiding potential impacts associated with livestock consumption of poor-quality feed. (NP 215)

Limited irrigation and fertigation can reduce climate impact. Irrigated farmland is some of the most productive agricultural land in the United States, but observations indicate that it is challenging to maintain crop yields and nutrient availability when water supplies are limited. ARS researchers in Fort Collins, Colorado, and Colorado State University collaborators tested alternative approaches to limited irrigation and other water saving strategies, including a process called drip fertigation, where nutrients are delivered via precisely-placed irrigation systems. Researchers found that limited irrigation reduced greenhouse gas emissions (GHG) by 15 to 50 percent and conserved water but reduced maize yield in some years. Findings also generally indicated that irrigated drip fertigation deployed in a sandy loam soil with little organic matter resulted in total GHG emissions that were one-tenth of literature-based measurements from sprinkler-irrigated maize systems. Both conserving water and reducing GHG emissions will be increasingly vital in developing sustainable agricultural systems in the arid western United States. These extremely low GHG emission values will be used to further refine the U.S. Agriculture and Forestry Greenhouse Gas Inventory, which catalogs best agricultural management practices. (NP 212)

Optimal precision placement of crops when managing a no-till system. As farmers adopt recommended no-till farming systems, precision placement of various crops within the no-till cropping system can minimize environmental impacts while maximizing crop yields. ARS researchers in El Reno, Oklahoma, used the Multi-objective Evolutionary Algorithm for Soil and Water Assessment Tool (SWAT-MEA) to determine optimal spatial placement of soybeans, winter wheat, grain sorghum, upland cotton, and peanut cropping systems under no-till production in Oklahoma's Fort Cobb Reservoir watershed. Results showed that under optimal crop placement, no-till management maintained crop yields and reduced nitrogen, phosphorus, and sediment losses by 45 percent, 32 percent, and 65 percent, respectively. These results also showed that the SWAT-MEA can potentially be used as a precision agriculture decision-making tool to determine optimal land use and management to minimize environmental impacts while maintaining yields. (NP 211)

A living mulch system enhances soil infiltration and reduces soil erosion in row crops. Corn and soybean farmers are encouraged to use winter cover crops for a variety of reasons, but it is challenging and expensive to replant them every fall. Perennial living mulches have been proposed as way to obtain the benefits of cover crops that need to be planted only once. ARS researchers in St. Paul, Minnesota, completed a 5-year project at two locations in the upper U.S. Midwest that examined the long-term environmental impact of growing corn and soybeans in a perennial living mulch of kura clover. While no differences were found in many soil properties, water infiltration rates were 10-19 times higher in the living mulch system compared to the conventional system. Storm runoff was also measured on sloped plots with both systems, and the living mulch system reduced erosive soil loss by 93 percent, compared to the conventional system. Perennial living mulch systems are a promising management practice for increasing infiltration rates, reducing runoff, and protecting surrounding surface water quality. (NP 211)

Monitoring and Mitigating the Spread of Plant Disease



ARS is committed to controlling plant diseases to ensure food security and an adequate supply of food and non-food crops for feed, fiber, and energy. In 2019, USDA estimated that plant diseases cost the U.S. agricultural industry $43 billion. This includes losses from crop yield, quality, and marketability. The most common plant diseases in the United States are caused by fungi, bacteria, and viruses. Plant diseases can be spread in a number of ways, including wind, water, insects, and animals. Effective control of plant diseases requires an understanding of the biology of disease-causing agents. The following accomplishments in 2022 highlight ARS successes in identifying and halting the spread of plant diseases.

Genes involved in plant defense in resistant durum wheat. The plant disease Fusarium head blight (FHB) is an important constraint to profitable durum wheat production in the upper U.S. Midwest and durum cultivars currently lack consistently high levels of FHB resistance. To identify new genes for disease resistance, ARS researchers in St. Paul, Minnesota, studied differences in the genes expressed by FHB-susceptible lines and a newly developed M4 line that has moderately high FHB resistance. During infection, the resistant M4 line activated many categories of genes associated with an active plant disease defense response. These genes are being further characterized to better define the mechanism of resistance and assist in breeding better cultivars. These new native sources of FHB resistance in durum wheat with the gene markers will be a great boon to the effort in breeding for resistant cultivars and the growers in the U.S. Upper Great Plains region. (NP 303)

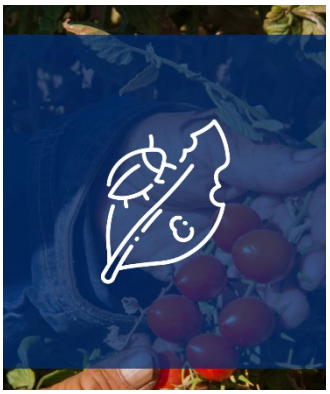
Machine learning approaches identify root microbial community members associated with Prunus replant disease. Prunus replant disease (PRD), affecting more than 10,000 replanted almond orchards every year, is a serious but poorly understood soilborne disease complex that suppresses tree development, efficient water and nutrient use, and crop yield. Integrated PRD management requires a better understanding of factors that drive its occurrence. Machine learning approaches focusing exclusively on root microbial populations resulted in identifying 26 bacteria, 2 oomycetes, and 2 fungi as top predictors of PRD induction. *Streptomyces scabiei*, *Steroidobacter denitrificans*, *Streptomyces bolbili*, and *Pythium mamillatum* were relatively abundant (5-43 percent) among the top predictors. The findings will guide future targeted testing of microbial taxa for PRD induction and suppression in roots. (NP 303)

New diagnostic method to detect a spinach pathogen in leaves. Downy mildew disease of spinach, caused by the plant pathogen *Peronospora effusa*, is the major disease constraint on spinach in the United States and worldwide. ARS researchers in Salinas, California, led the effort to develop a species-specific detection system that can be used in the field. The DNA-based system can be deployed from a pickup truck, detecting the pathogen within 3 to 4 hours. This new early detection technology will help growers target fungicide applications more effectively prior to symptom development and help prevent downy

mildew epidemics. Since nearly 45 percent of U.S. spinach is organic, the technology is especially helpful to organic growers who can choose to harvest organic crops earlier and avoid symptom development that renders their product unmarketable. Results are published in the peer-reviewed journal Plant Disease. (NP 303)

Fusarium strains and climate change factors have different influences on mycotoxin contamination of cereal crops. Fusarium fungi are devastating pathogens that infect cereal crops. They cause billions of dollars in annual yield losses and poison grains with mycotoxins, making them unsafe to eat. Climate change is predicted to increase the frequency and severity of Fusarium disease and mycotoxin contamination of cereal grains. However, it has been unclear how rising atmospheric carbon dioxide and temperature will specifically impact Fusarium graminearum ear rot of corn and head blight of wheat. ARS researchers in Peoria, Illinois, showed that both economically important crops were more susceptible to mycotoxin contamination when grown at elevated carbon dioxide, but warmer temperatures reduced mycotoxin contamination. Additionally, the effects of carbon dioxide and temperature were dependent on the F. graminearum strain, and, under combined stress conditions, a strain that produced the highest mycotoxin levels in corn produced the lowest levels in wheat. This study provides valuable information needed by producers (farmers) and regulatory agencies to determine the risk of Fusarium disease outbreaks and mycotoxin contamination in the future. (NP 108)

Controlling Insect Pests to Protect Plant, Animal, and Human Health



Insecticide resistance is a major challenge to U.S. agricultural production, public health, and the environment. Insecticide resistance occurs when insects develop the ability to survive exposure to a pesticide that would normally kill them. This can happen when insects are exposed to low doses of the pesticide over time, or when they inherit genes for resistance from their parents. The rapid evolution of insecticide resistance in insect pest populations can make chemical controls ineffective and unsustainable, so effective alternative management strategies for these insect pests are needed. To address this, ARS is researching organic biopesticides and encasing the biopesticides with nanoparticle-based formulations and generated the following accomplishments in FY 2022.

Two natural substances are excellent insecticides against spotted wing drosophila. Spotted winged drosophila (SWD) is an intractable pest of small fruit crops and is effectively controlled in conventional agriculture by powerful synthetic insecticides. In contrast, organic berry producers have only two control options, but the effectiveness of these products varies considerably. ARS researchers in Poplarville, Mississippi, and Miami, Florida, and University of Hawaii cooperators identified two compounds from pennyroyal and basil plants that were neurotoxic to SWD and that killed more than 60 percent of eggs and adult flies in blueberry fields. Laboratory tests revealed these compounds eliminated SWD reproduction at concentrations of 0.5 percent. These monoterpene substances are readily available and are being formulated as a new organically certified biopesticide targeting small-bodied crop pests. (NP 305)

Nanoparticle formulations enhance biopesticide efficacy. Environmentally friendly biopesticides such as entomopathogenic (insect-killing) nematodes and fungi can control various economically important insect pests such as pecan weevil and peachtree borer. However, the efficacy of these biopesticides can be limited due to their sensitivity to ultraviolet radiation, so it is critical to develop new formulations that protect the biopesticide organisms from environmental stress. ARS researchers in Byron, Georgia, have a research agreement with the Agricultural Research Organization Volcani Center in Israel that is directed toward developing novel formulations for biopesticides based on nanotechnology. ARS and Israeli partners discovered that nanoparticle-based formulations protect biopesticides from ultraviolet radiation

and thereby increase pest control efficacy. This technology can lead to improved sustainability in pest management practices. A patent application is being submitted based on the discovery. (NP 304)

New integrated pest management tactics for stored product insects with phosphine resistance. The abundance and range of stored product insect pests with phosphine resistance are increasing around the world. Phosphine is one of the most commonly used fumigants in large warehouses and food facilities for insect control, and the emergence of resistance threatens its efficacy, which has become a key stakeholder concern. Long-lasting insecticide-incorporated netting (LLIN) and packing material containing insecticides have been effective against several species of stored product insects. ARS researchers in Manhattan, Kansas, evaluated the efficacy of LLIN and packaging materials containing four different active ingredients (deltamethrin, permethrin, indoxacarb, and dinotefuran) against phosphine-resistant populations of lesser grain borer and red flour beetle. Overall, all compounds caused significant mortality in phosphine-resistant strains of both species, with the exception of indoxacarb for red flour beetle. Using bags and netting impregnated with insecticides provides new tools to prevent and reduce infestations of stored product insects, including those that have evolved resistance to phosphine. (NP 304)

Development of lettuce varieties with resistance to leafminers, corky root, and downy mildew. Leafminers, corky root, and downy mildew are major pests and diseases of lettuce, and the most cost-effective controls are achieved through resistant cultivars. ARS researchers in Salinas, California, developed and released two green leaf, one red leaf, and two romaine lettuce varieties with resistance to these pests and diseases. The varieties may be used for commercial production and can be used by other public and private breeders as sources of resistance in developing new lettuce cultivars. (NP 301)

Improving Pasture and Rangeland Management

The ARS pasture and rangeland management research program enhances the utility, function, and performance of rangelands, pastures, forage, and turf agroecosystems while providing ecosystem services. However, challenges such as wildfire, invasive weeds, climate change, and thin profit margins threaten grass, forage, and rangeland agroecosystems across the United States. ARS is developing and integrating improved management practices, germplasm, and land-use strategies to optimize vegetation, livestock, and natural resource management on private and public lands. Some of these accomplishments from 2022 are documented below.

Virtual fencing helps grazing cattle reduce vegetation in fuel breaks to fight wildfires. The frequency and severity of large wildfires are increasing in western U.S. rangelands, and invasive annual grasses are a significant fuel source for rangeland wildfires. Research is showing that targeted cattle grazing of these grasses in strategic locations can create fuel breaks that help reduce wildfire spread but keeping cattle within targeted fuel break boundaries without fencing is a challenge. ARS researchers in Burns, Oregon, tested the effectiveness of innovative, virtual fencing technology for keeping grazing cattle within the bounds of a pasture-scale fuel break in southeast Oregon's sagebrush steppe. Virtual fencing was highly effective in containing dry cows and reducing vegetation fuels within fuel break boundaries but was less effective for cows with calves. Cattle consumed about 50 percent of the fine fuel biomass within a 200 x 3000 meter virtually-fenced fuel break, compared to about 5 percent of the biomass outside of the fuel break. Virtual fencing, particularly when combined with geospatial technologies for mapping grass fuel accumulations, has strong potential for strategically managing the abundance of grass fuel within fuel breaks and potentially larger rangeland landscapes and could benefit a wide variety of rancher needs. (NP 215)

New technologies advance precision livestock grazing and rangeland management. Tools are needed to help ranchers rapidly respond to changing forage conditions during the grazing season. In extensive rangeland systems, it is often impractical to measure forage availability and quality in the field, and

existing remote sensing technologies do not provide grazing managers with near-real-time, production-relevant metrics, such as available plant biomass, diet quality, or animal weight gain, at spatial scales relevant for management decisions. ARS scientists in Fort Collins, Colorado, linked long-term, field-based datasets with freely available satellite data to accurately predict daily plant biomass, diet quality, and animal weight gains across highly variable conditions. These remote sensing advances yield near-real-time plant biomass and diet quality maps at fine (100 feet) spatial scales to assist managers with ranch- and pasture-scale decision-making. In related research, ARS scientists in Fort Collins, Colorado, and University Park, Pennsylvania, tested innovative sensors on free-ranging beef cattle in seven states from the U.S. West to Florida to quantify cattle foraging behavior and distribution. Topographical variations consistently affected cattle distribution on grazing lands. Integrating three animal sensor types—GPS tracking collars, accelerometers, and jaw movement devices—revealed how daily metrics of foraging behavior are influenced by grazing management and give managers real-time indicators of how forage conditions affect livestock intake and weight gains. These near-real-time tools, combined with commercially available technologies such as virtual fencing, open a new frontier for precision livestock management in extensive rangelands to accurately match forage supply with animal demand, which increases efficiency and lowers environmental impact. (NP 215)

Developing strategies to support invasive annual grass management. Invasive annual grasses such as bromes (*Bromus* spp.), ventenata (*Ventenata dubia*), and medusahead (*Taeniatherum caput-medusae*) are problematic throughout arid and semi-arid rangeland ecosystems in the U.S. West, with substantial impacts to ecosystem health and forage productivity. ARS researchers in Sidney, Montana, and collaborators are developing effective control strategies that reduce wildfire spread and are documenting invasive annual grass responses to fire in the U.S. Great Plains. Researchers employed U.S. Forest Service fire spread models in a first-of-its-kind exercise to determine which plant traits contribute to effective greenstrips (linear strips of less-flammable species planted to interrupt wildfire spread) that provide fire protection and staging areas for firefighters to safely initiate control operations. Field data and remotely sensed products were also combined to verify that rangeland fire management in the eastern Great Plains is compatible with strategies to limit the frequency and abundance of invasive annual grasses. These "lessons learned" from the Great Plains were included in national efforts to describe the total ARS research impact on invasive annual grass management. (NP 304)

Bluebunch wheatgrass and Sandberg's bluegrass can be harvested and stored. Restoring invaded and degraded rangelands is central to recovering the health and function of rangeland throughout the western United States. Federal land managers and livestock producers in this region have found restoring these systems is very difficult because native plants rarely establish from seeds. ARS scientists in Burns, Oregon, are working on a novel restoration system that includes using buds that are collected from native plant crowns and stored for planned restoration efforts. Their findings suggest that buds of bluebunch wheatgrass and Sandberg's bluegrass can be harvested mechanically and stored at about 40° F. They also found that stored bud viability increases with increasing amounts of supporting material. This is critically important to developing new restoration systems because crowns must be easily collectible and storable to be useful to managers. (NP 304)

Looking Ahead

Each dollar invested in agricultural research results in $20 of economic impact. However, U.S. agriculture faces a growing number of complex challenges, including labor shortages, rising input costs, weather volatility, trade uncertainty, and climate change. Fortunately, agricultural producers can count on ARS researchers to respond with agility, innovation, and relevance. ARS is dedicated to conducting research with bold action, collaborative leadership, active dialogue, and a deep commitment to serving all Americans now and into the future.