USDA

United States Department of Agriculture

Agricultural Research Service

2020 ANNUAL REPORT

ARS REPORT ON SCIENCE

CONTENTS

INTRODUCTION

USDA'S AGRICULTURAL RESEARCH SERVICE (ARS) AT A GLANCE

Mission: ARS delivers scientific solutions to national and global agricultural challenges.

Vision: Global leadership in agricultural discoveries through scientific excellence.

Core Values

The ARS core values underpin the agency's commitment to delivering cutting-edge, scientific tools and innovative solutions for American farmers, producers, industry, and communities to support the nourishment and well-being of all people; sustain our nation's agroecosystems and natural resources; and ensure the economic competitiveness and excellence of our agriculture.

- Scientific excellence
- Creativity
- Innovation
- Integrity
- Leadership
- Collaboration
- Accountability
- Transparency
- Diversity
- Respect
- Inclusiveness
- Public Service

ARS Administrators

Chavonda Jacobs-Young
ARS Administrator

Steven Kappes
ARS Associate Administrator of National Programs

Simon Liu
ARS Associate Administrator of Research Management and Operations

Our Focus

- Animal Production and Protection
- Crop Production and Protection
- Natural Resources and Sustainable Agricultural Systems
- Nutrition, Food Safety, and Quality

How We Get It Done

- 660 research projects
- 8,000 employees
- 90+ research locations
- $1.4 billion budget

FY 2020 Outputs

3,933
peer-reviewed journal articles

76
patent applications filed

50
patents issued

93
licenses

47
varieties or germplasm lines

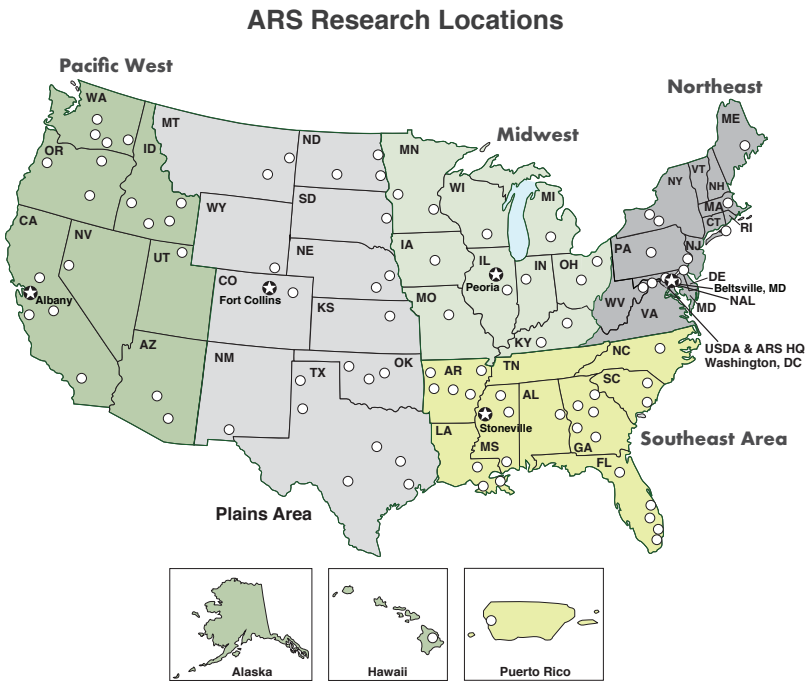
SPECIALIZED INFRASTRUCTURE AND CAPABILITIES

State-of-the-art Facilities such as:

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

Special Collections, 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 Herbarium
- U.S. National Fungus Collections



Premier Networks of Scientific Expertise, including:

- Long-Term Agroecosystem Research Network, for developing 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 through reduced soil emissions of greenhouse gases
- Resilient Economic Agricultural Practices (REAP), for improving soil health and resiliency through improved management practices
- Partnerships for Data Innovations, for developing precision field monitoring systems and managing big data in agriculture
- Breeding Insight, for accelerating small breeding programs through the combination of modern 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 OVERVIEWS

FOR MORE INFORMATION: www.ars.usda.gov/animal-production-and-protection/

ARS ANIMAL PRODUCTION AND PROTECTION RESEARCH

Research of the ARS Animal Production and Protection National Programs improves the health, well-being, and efficiency of livestock, poultry, and aquatic food animals to ensure a productive and safe food supply. These research programs provide the scientific information and tools to support U.S. food animal industries as they supply the nutritious animal products required by the nation, compete successfully in worldwide trade, and contribute toward global food security. The program also addresses the many veterinary problems created by arthropod pests and vectors and zoonotic diseases, producing solutions to protect the health and well-being of American citizens.

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 the nation's agriculture and food supply through improved disease detection, prevention, and control;
- Improves domestic aquaculture production efficiency and product quality while minimizing impacts on natural resources; and
- Eliminates arthropod vectors and the diseases they transmit to livestock, humans, and other animals and reduces their economic impact.

Looking ahead, ARS will continue to prioritize the development of precision agricultural management tools to detect and manage environmental stress, estrus, disease and behavior. ARS also looks to improve genomic and transcriptomic data to understand gene expression in different tissues at different animal developmental stages.

ARS is also working with the U.S. Department of Homeland Security to bring online 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-4) in the United States to study high-consequence zoonotic diseases affecting large livestock. This facility will enhance existing research programs and expertise in foot-and-mouth disease, African swine fever, Japanese encephalitis, and Rift Valley fever; and initiate new research and expertise in zoonotic disease agents and new arthropod-borne diseases. NBAF construction activities are nearly complete; facility commissioning will be finished in December 2021, and the facility will be fully operational in 2023.

FOR MORE INFORMATION: www.ars.usda.gov/crop-production-and-protection/

ARS CROP PRODUCTION AND PROTECTION RESEARCH

The ARS Crop Production and Protection National Programs deliver science-based information, genetic resources, and technologies for increased crop productivity, economically and environmentally sustainable methods of crop production, and crop protection from diseases and pests. Research conducted under these programs supports the needs of producers, consumers, workers, the public, and the global community by increasing crop productivity and value; ensuring a ready supply of high quality, safe, affordable, and nutritious food; 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; and
- Provides technology to manage pest populations below economically damaging thresholds through the integration of environmentally compatible strategies that are based on increased understanding of the biology and ecology of insect, mite, and weed pests.

ARS is steward to important national agricultural resources for protecting U.S. agriculture, including the National Plant Germplasm System (distributed over 20 locations), Overseas Biological Control Laboratories (4 locations), the U.S. National Arboretum, 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 National Sclerotinia Initiative, the National Plant Disease Recovery System, the 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 (www.breedinginsight.org), which provides breeders with direct access and support to 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, and trout breeding and will expand its portfolio to more than 50 specialty breeding programs over the next 5 years.
- I5k and Ag100Pest, which seeks to sequence the genomes of 5,000 insects and mites, including the top 100 agricultural pests in the United States. Thus far, ARS scientists have sequenced key invasive pests such as the Asian citrus psyllid, brown marmorated stink bug, spotted lanternfly, and Asian giant hornet.

Additionally, ARS fosters research synergies that cut across the continuum of science to achieve breakthrough innovations. Crop Production and Protection leads many such projects. For example, four projects focus on renewing of oat germplasm, improving potato breeding efficiency, preventing citrus greening, and enhancing greenhouse vegetable production.

FOR MORE INFORMATION: www.ars.usda.gov/natural-resources-and-sustainable-agricultural-systems/

ARS NATURAL RESOURCES AND SUSTAINABLE AGRICULTURAL SYSTEMS RESEARCH

The ARS Natural Resources and Sustainable Agricultural Systems National Programs develop technologies and strategies that help farmers, ranchers, and other managers effectively steward the diverse agricultural mosaic spread across the nation. These diverse landscapes—western rangelands where livestock graze, midwest and southern croplands, coastal valleys and plains used to grow high-value produce—generate more than $200 billion in goods and services that are the basis of a strong rural economy.

The ARS Natural Resources and Sustainable Agricultural Systems research programs investigate and develop tools and methods for:

- Effectively and safely managing 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
- Integrated solutions for agriculture enabling greater productivity, profitability, and natural resource enhancement.

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, accelerating agricultural research. 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 recently completed 5-year review of the Hubs confirmed that the 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 the Greenhouse gas Reduction through Agricultural Carbon Enhancement network (GRACEnet), and the Resilient Economic Agricultural Practices (REAP) program.

FOR MORE INFORMATION: www.ars.usda.gov/nutrition-food-safetyquality/

ARS NUTRITION, FOOD SAFETY, AND QUALITY RESEARCH

The ARS Nutrition, Food Safety, and Quality National Programs maintain a healthy and safe food supply while improving the economic viability and competitiveness of American agriculture by enhancing the quality and utilization of agricultural products for the benefit of 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 pathogens, toxins, and chemical contamination during production, processing, and preparation; and
- Improves postharvest quality and develops new uses for agricultural products.

One of the defining features of these programs is an emphasis on food-based approaches to improve human health. The ARS Human Nutrition Research Program hosts six internationally-recognized Human Nutrition Research Centers with the core capability for long-term, multidisciplinary, translational research in high priority areas and the availability of premier scientists, state-of-the-science equipment, and facilities for human research across the life cycle. This program leverages unique national resources, including the National Nutrient Data Laboratory, the Food Surveys Research Group (which conducts the What We Eat in America survey), and a laboratory that develops and improves methods for food analysis.

The ARS Food Safety program plays a critical role in developing tests and processes that keep the food supply safe and reduce and control pathogens and toxins in agricultural products. The program involves both national and international collaborations and delivers research results and advances to regulatory agencies, commodity organizations, industry, academia, and research and extension agencies and consumers.

The ARS Product Quality and New Uses program focuses on developing knowledge and enabling commercially-viable technologies to 1) measure, maintain, and enhance post-harvest product quality; 2) harvest and process agricultural materials, and 3) create new value-added products. These research activities focus on food products, non-food products, and biorefining. The innovative production of bioproducts using renewable non-food, low-value plant and animal resources meets consumer demands for sustainable high-value products that increase farmer's profits.

FOR MORE INFORMATION: www.ars.usda.gov/office-of-international-research-engagement-and-cooperation/

ARS 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 international research cooperation provides solutions to current and future agricultural productivity and sustainability challenges beyond what can be achieved through purely domestic research. 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 contact for international activities in ARS. Working with the ARS Office of National Programs, OIREC regional international affairs specialists catalyze strategic international partnerships that can enhance the productivity, effectiveness, and impact of ARS National Programs, as well as further the goals of the United States government.

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

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

The four strategically located ARS Overseas Biological Control Laboratories enable ARS to study and partner with countries that are the sites of origin for invasive species; these studies advance future U.S. mitigation efforts:

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

FOR MORE INFORMATION: www.ars.usda.gov/office-of-technology-transfer/

ARS 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 to 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 research purposes (non-commercial).

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 (ARP) Network;
- Leads and engages with the Agricultural Technology Innovation Partnership (ATIP) 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
- Encourage the implementation of innovative methods of conducting technology transfer;

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

FOR MORE INFORMATION: www.nal.usda.gov/

NATIONAL AGRICULTURAL LIBRARY

The National Agricultural Library (NAL) sustains the American 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.

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

- AGRICOLA **(www.agricola.nal.usda.gov/)**, USDA's online catalog and index to the agricultural literature;
- PubAg **(pubag.nal.usda.gov/)** and Ag Data Commons **(www.data.nal.usda.gov/)**, USDA's "one-stop shop" for public access to scholarly literature and data funded by the Department;
- NAL Digital Collections **(www.naldc.nal.usda.gov/)**, including digitized content from NAL's Special Collections; and
- DigiTop **(www.digitop.nal.usda.gov/)**, the online resource for USDA staff that provides 24/7/365 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 internal and external partners and 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 improve 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.

FOR MORE INFORMATION: www.usna.usda.gov/

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, conservation of genetic resources, 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.

Located in Northeast Washington, D.C., USNA connects people with plants in a serene urban oasis with unique collections, gardens, and natural settings. The 446-acre arboretum arboretum boasts 16 major gardens and attracts more than 600,000 visitors annually.

Research at USNA includes:

- Wide-ranging developmental and applied research on trees, shrubs, turf, and floral plants;
- Development of new technologies for the floral and nursery industries;
- Development of superior landscape plants through a program of genetic improvement, evaluation, and selection;
- Research on the taxonomy and nomenclature of ornamental plants and their wild relatives; and
- Collection, preservation, and distribution of ornamental plant germplasm.

Additionally, USNA boasts a permanent reference collection of more than 650,000 specimens of dried pressed plants for scientific studies in agriculture, horticulture, botany, medicine, and other related fields. This herbarium contains plants collected from around the world and places special emphasis on cultivated plants. Groups with particularly robust representation include azaleas, cherries, daffodils, daylilies, hollies, oaks, viburnums, and willows.

TOP 2020 RESEARCH ACCOMPLISHMENTS

PART 1. WHAT ARS DOES: IMPROVING CROP, LIVESTOCK, AND AQUACULTURE PRODUCTION

FOR MORE INFORMATION: www.ars.usda.gov/Developing-new-crop-varieities-with-enhanced-traits-and-disease-resistance/

DEVELOPING NEW CROP VARIETIES WITH ENHANCED TRAITS AND DISEASE RESISTANCE

ARS advances multiple crop industries by developing new crop varieties with disease resistance and other trait enhancements and providing new tools and approaches that will support future breeding efforts. In addition to supporting major commodities, ARS breeding programs advance specialty crops, which alone have a U.S. farm gate value of $87.7 billion. The following accomplishments are examples of ARS advances in crop breeding for disease resistance and trait enhancement that were made in FY 2020.

Identification of romaine lettuces with reduced browning discoloration for fresh-cut processing. Lettuce is one of the top 10 most valuable crops in the United States, with an annual farm-gate value of more than $2.5 billion. Fresh-cut lettuce is the primary ingredient of the increasingly popular packaged, ready-to-eat salads; however, discoloration (browning) represents a major challenge that limits its quality and shelf life. ARS researchers in Salinas, California, and Beltsville, Maryland, identified lettuces with limited browning that will be used in breeding programs and to help identify genes associated with limited browning.

> **ARS researchers identified lettuces with limited browning that will be used in breeding programs.**

Reducing preharvest sprouting (PHS) in soft winter wheat. PHS is the germination of wheat grains in the field before harvest following 2 or more consecutive days of rain with cool temperatures. It can cause farmers to lose approximately 30 percent of their crop value, translating into approximately $420 million annually in the United States. Because its genetic nature is not well understood, few markers exist for breeders to use in developing resistant lines. ARS scientists in Wooster, Ohio, identified nine PHS-tolerant soft winter wheat varieties that hold potential for future breeding of PHS resistance.

Potato postharvest quality evaluations and release of new potato cultivars. Acceptable processing quality after storage is an essential attribute of a successful potato variety. ARS scientists in East Grand Forks, Minnesota, play a critical role in the overall process for evaluating and releasing new cultivars by Federal and State cooperators nationwide. In the past year, the team screened 139 advanced breeding lines for storage/processing quality. Since 2015, they have identified 17 chip clones and 14 fry processing clones that have superior storage quality. These identified clones were advanced through other national trial evaluations; since 2015, 4 chipping varieties and 14 fry varieties have been released.

Identification of blueberry species with fruit fly resistance. Spotted wing drosophila fruit fly causes more than $511 million in damage annually to fruit production in Western states. ARS scientists from Corvallis, Oregon, and Poplarville, Mississippi, screened 29 blueberry species for resistance to fruit fly feeding and identified 10 resistant species. Most highbush blueberry cultivars were susceptible, but rabbiteye and other blueberry cultivars with smaller, firmer fruit types were resistant. These findings will enable blueberry breeders to produce new blueberry cultivars resistant to this fruit fly.

FOR MORE INFORMATION: www.ars.usda.gov/Advancing-Sustainable-Livestock-Production/

ADVANCING SUSTAINABLE LIVESTOCK PRODUCTION

The ARS food animal production research program improves food animal production efficiency, sustainability, animal welfare, and product quality while safeguarding animal genetic resources. Animal production is a critical component of the U.S. economy, yielding $440.7 billion in economic output, with $76.7 billion in earnings, $19.6 billion in income taxes, and $7.4 billion in property taxes in 2014. The following accomplishments highlight ARS advances in animal production research in FY 2020.

A high-quality cattle gene atlas. ARS scientists in Beltsville, Maryland, developed a high-quality resource for discovering the tissues, genes, and genome structure that control traits in cattle. This comprehensive "gene atlas" helps identify the genes and the specific changes within genes responsible for differences in traits between animals. It also identifies the tissues throughout the body responsible for expression of these traits. This gene atlas will be a critically important resource for improving important livestock traits.

New, affordable method for conducting genomic analyses of crossbred cattle. ARS researchers in Clay Center, Nebraska, developed a new method for studying trait-genome associations in crossbred cattle that is more effective and costs less than currently available technologies. This new approach will enable producers to study more cattle and conduct finer-scale genomic analyses of these cattle. Ultimately, this new method will improve selection accuracy and increase genetic gain, leading to a faster rate of improvement in valuable beef traits for the industry.

> **"This new method will improve selection accuracy and increase genetic gain, leading to a faster rate of improvement in valuable beef traits for the industry."**

New method to improve the identification of genetic markers for feed efficient pigs. Genetic markers enable breeders to efficiently and affordably screen thousands of individuals and select the subset of individuals with the desired traits. ARS scientists in Clay Center, Nebraska, developed a methodology using gene expression data to develop genetic markers for feed efficiency in pigs and found 36 markers associated with feed efficiency. The markers identified in this study are available to commercial genotyping companies working with producers to improve pig feed efficiency.

Weaning-associated fungus *Kazachstania slooffiae* likely has positive role in piglet growth and health. Dramatic changes in fungal microorganisms after piglet weaning may contribute to the growth and health of weaned piglets. ARS scientists in Beltsville, Maryland, conducted genomic analyses of *Kazachstania slooffiae*, the most dominant post-weaning fungus in healthy piglets, and found that it has positive interactions with beneficial bacteria in the piglet gut. These results support the concept that *Kazachstania slooffiae* can be used as a naturally derived probiotic to enhance piglet growth.

FOR MORE INFORMATION: www.ars.usda.gov/Advancing-Sustainable-Aquaculture-Production/

ADVANCING SUSTAINABLE AQUACULTURE PRODUCTION

The ARS aquaculture research program delivers new knowledge and technologies that improve domestic aquaculture production efficiency and product quality while minimizing impacts on natural resources. This work advances the efforts of more than 2,900 aquaculture farmers who produce more than $1.5 billion worth of goods annually to meet the market demand generated by 300 million U.S. consumers. The following accomplishments highlight ARS FY 2020 advances in catfish, trout, pompano, and salmon production.

Delta Select strain of channel catfish released to industry. ARS researchers in Stoneville, Mississippi, developed the 'Delta Select' strain of channel catfish, which has a 25 percent increase in growth rate and 0.9 percent increase in carcass yield compared to the control line originating from the same population. ARS released approximately 90,000 head (180,000 pounds) of 2-year-old Delta Select catfish to industry, providing U.S. farmers access to improved catfish germplasm that will reduce production costs and make farmers more efficient, profitable, and competitive in the global seafood market.

> **The Delta Select strain of channel catfish has a 25 percent increase in growth rate and 0.9 percent increase in carcass yield.**

A bacteriophage for preventing disease in rainbow trout. Bacteriophages (phages) are viruses that infect and kill bacteria. Used against disease-causing microbes, phages are excellent candidates for preventing or treating of bacterial diseases. ARS researchers in Leetown, West Virginia, identified a new phage that kills *Yersinia ruckeri*, the rainbow trout pathogen. In addition to directly infecting and killing *Yersinia ruckeri*, the phage increases the bacteria's susceptibility to the trout immune system, preventing its survival inside its fish host.

A draft genome sequence for Florida pompano. The lack of available genome information is a hurdle in implementing state-of-the-art selective breeding strategies for many aquaculture species, including Florida pompano. ARS-funded researchers in Fort Pierce, Florida, established a complete draft genome of the Florida pompano by using a hybrid sequencing method and novel bioinformatics workflow. This draft genome will improve farm production and profitability and enhance breeding strategies by identifying genes associated with aquaculture production efficiency and product quality.

Genome-enabled breeding tools for Atlantic salmon. The number of U.S. commercial Atlantic salmon farming operations is expected to increase 5-fold over the next 3 years, and demand for genetically improved stocks will increase dramatically. ARS researchers in Franklin, Maine, and Leetown, West Virginia, created an improved genome reference sequence for the North American Atlantic salmon and developed the first DNA chip for Atlantic salmon, thereby enabling the use of genomic information in breeding strategies. This DNA chip is publicly available and in use by commercial breeding programs.

TOP 2020 RESEARCH ACCOMPLISHMENTS

PART 2. WHO ARS SERVES: SUPPORTING CONSUMERS, FARMERS, COMMUNITIES, AND RESEARCH PARTNERS

FOR MORE INFORMATION: www.ars.usda.gov/Advancing-Human-Nutrition-Research/

ADVANCING HUMAN NUTRITION RESEARCH

The ARS human nutrition research program enhances the quality of the American diet and improves health through research. Obesity is estimated to cost $190 billion annually, and as its prevalence has increased over recent decades, ARS scientists have researched innovative ways of reversing that trend. Since agriculture primarily produces food for human consumption, integrating human nutrition research into ARS is critical for solving the biggest problems facing producers and consumers. The following accomplishments highlight ARS advances human nutrition research in FY 2020.

Dietary carbohydrate intake contributes to reduced stress. ARS scientists in Davis, California, found that the Dietary Guidelines for Americans (DGA)-based diet reduced concentrations of a key stress response hormone, cortisol, and dampened stress-induced cortisol reactions. The DGA diet includes more dietary carbohydrates than the less healthy typical American diet. These findings suggest that, in the context of a healthy diet, carbohydrate consumption may provide some protection from stress-related disease risk. This stress and cortisol dampening effect associated with the DGA could reduce stress-related eating and make it easier to sustain a healthier diet.

> **In the context of a healthy diet, carbohydrate consumption may provide some protection from stress-related disease risk.**

Breastfeeding alters gut bacteria, impacts immune health in infants. ARS-supported scientists in Little Rock, Arkansas, found that breastfeeding resulted in greater amounts of bacteria that produce compounds that serve as signals in development of the gut and other organs. Additionally, bacterial metabolites that optimize immune response and inhibit allergy were higher in breastfed infants. This new information adds to the scientific basis for the recommendation by the Centers for Disease Control and Prevention to breastfeed infants when possible.

First ever expert advice to parents and caregivers on healthy eating behaviors in young children. The first 5 years of life are a critical period for helping children learn how to regulate their food intake to match their energy needs. ARS-supported researchers in Houston, Texas, led a partnership with other scientific experts and the American Heart Association to release their first scientific statement giving advice on how to foster healthy eating behaviors in children under 5 years of age. This guidance will broadly reach parents and caregivers across the country and provide strategies for healthy eating behaviors with the goal of reducing childhood obesity.

Obesity dampens immune responses in young women to levels similar to those of elderly. Both obesity and aging are associated with muted immune and inflammatory responses. In a study of 44 women, ARS-supported scientists in Boston, Massachusetts, found that older women with obesity (age 60-83) had significantly fewer circulating immune cells of four specific types than young women with obesity (age 23-43). With few exceptions, however, there was no significant difference in inflammation markers in two types of immune cells. These findings call for further investigation into the impact of obesity on premature aging of the immune system.

FOR MORE INFORMATION: www.ars.usda.gov/Reducing-Labor-and-Advancing-Precision-Agriculture-through-Automation/

REDUCING LABOR AND ADVANCING PRECISION AGRICULTURE THROUGH AUTOMATION

ARS advances labor-saving tools and technologies to aid in breeding and production of crops and livestock, improve preharvest and postharvest processing, and enable nondestructive commodity quality assessment and grading. Current agricultural science incorporates crosscutting advances in technology, automation, informatics, and remote sensing to help industry address labor shortages, fine-tune management decisions, conserve resources, and meet growing demands for food. The following advances in FY 2020 highlight this growing focus.

ARS develops the first automated peanut sampling system. The USDA Agricultural Marketing Service (AMS) uses a labor-intensive process to assess the quality and value of every load of peanuts a farmer delivers for sale. ARS engineers in Dawson, Georgia, designed and installed instrumentation that reduces the reliance on seasonal labor and improves the consistency and accuracy of the sampling used for determining peanut quality and value. AMS personnel conducted tests for 2 years and have approved the control system for installation for official sampling at commercial peanut facilities.

Universal intelligent spray control system benefits the environment, saves growers money. ARS researchers in Wooster, Ohio, developed a universal intelligent spray system as a retrofit unit for conventional orchard sprayers. This new technology can deliver pest and disease control that is as effective as conventional spray systems while reducing pesticide use as much as 85 percent, resulting in an annual chemical cost saving of $812 per acre. Smart Guided Systems, LLC, commercialized the technology, and citrus, apple, grape, nursery, and pecan growers have started to upgrade their sprayers with this system.

> **This new technology can reduce pesticide use as much as 85 percent, resulting in an annual chemical saving of $812 per acre.**

Breeding Insight supports ARS specialty crop and animal breeders. ARS is accelerating and transforming small breeding programs through Breeding Insight (www.breedinginsight.org), which provides breeders with direct access to customized tools, informatics, and database technologies to adopt modern genomics pipelines to their programs. The project is in a pilot phase focused on blueberry, table grape, sweet potato, alfalfa, rainbow trout, and Atlantic salmon, with the future goal of expanding to all ARS specialty crop, animal, and natural resource breeding programs.

Affordable, portable system for rapid crop assessment and precision management. Manually collecting data about an organism's physical characteristics (phenotype) is important for breeding better crops but is very time-consuming and requires a lot of labor. An ARS researcher in Maricopa, Arizona, developed a low-cost wireless high-throughput phenotyping system powered by a solar rechargeable battery. This portable system can be mounted to drones for field use or to platforms in greenhouses or vertical farms. This system has the potential to be adapted for use in commercial precision agriculture.

FOR MORE INFORMATION: www.ars.usda.gov/Improving-Rural-Economies-through-New-Uses-of-Agriculturally-based-Materials/

IMPROVING RURAL ECONOMIES THROUGH NEW USES OF AGRICULTURALLY-BASED MATERIALS

ARS research enhances the economic viability and competitiveness of U.S. agriculture by improving the quality and marketability of harvested foods and agricultural feedstocks to meet consumer needs while developing environmentally friendly and efficient processing concepts. The following FY 2020 accomplishments illustrate how ARS researchers achieve this by using agricultural products or byproducts to develop new, innovative, and environmentally friendly products and technologies.

Improved packaging film made from renewable, inexpensive cotton waste materials. Poly (vinyl alcohol) (PVOH) is a plant-derived, water-soluble, and biodegradable compound that holds promise for mitigating the accumulation of nondegradable plastics in landfills and oceans. ARS scientists in Peoria, Illinois, discovered that blending PVOH with cotton processing waste results in a low-cost, biodegradable material suitable for plastics and packaging film. This value-added application of U.S. cotton coproducts benefits U.S. cotton farmers while mitigating plastic pollution.

> **"This value-added application of U.S. cotton coproducts benefits U.S. cotton farmers while mitigating plastic pollution."**

Improved antifogging agent derived from wheat, soybean, or milk protein. ARS scientists in Peoria, Illinois, have developed an antifogging agent that outperforms commercial antifog solutions. Antifogging treatment prevents the formation of fog-like droplets on the surface of glass or plastic used for windows, eyeglasses, and goggles. Because the new product is made using proteins derived from wheat, soybean, or milk, farmers and stakeholders in these value chains will benefit from this new use of agriculturally-based materials.

High-value applications of corn stover. ARS scientists in Peoria, Illinois, developed methods to derive nanocellulose from corn stover—the leaves, stalks, and cobs of corn plants left over in a field after harvest. Nanocellulose provides value in many products and end uses, including medical devices, cosmetics, and waste treatment. To enable the production of these products from corn stover-derived nanocellulose, ARS scientists determined the basic flow properties for transferring nanocellulose suspensions. Corn producers and processors will benefit from developing a high-value use from corn stover.

New analytical techniques to characterize silver nanoparticle-treated textiles. Manufacturers add silver nanoparticles to clothing to kill bacteria and fungi and the odors they cause. Safe and reliable nanoparticle-enhanced products require proper analytical techniques that evaluate the resulting technologies and products. ARS researchers in New Orleans, Louisiana, developed two simple, cost-effective, fast, and accurate methods to quantify silver nanoparticles. These methods outperform previously available techniques that are complicated, destructive, expensive, and time consuming.

FOR MORE INFORMATION: www.ars.usda.gov/Expanding-Public-Access-to-Agricultural-Information/

EXPANDING PUBLIC ACCESS TO AGRICULTURAL INFORMATION

ARS maintains effective stewardship of agricultural data, literature, and other information resources through the National Agricultural Library (NAL), the world's largest collection of agricultural information. As the library of the USDA, NAL provides public access to scholarly literature and data funded by the Department and digitized access to special collections. The following FY 2020 milestones demonstrate how NAL supports fact-based, data-driven decision-making.

Expanding access to nutrition-related information. In collaboration with major industry partners, ARS hosts FoodData Central (www.fdc.nal.usda.gov/), a public-access online reference containing entries for more than 358,117 different foods and 6.17 million food nutrients. Combined, the FoodData Central platform and the legacy Food Composition Database generated nearly 20 million pageviews and more than 2.7 million user sessions in FY 2020. Application developers made nearly 255 million application programming interface (API) calls against these two data products in FY 2020, making these APIs among the most popular in government.

> **Combined, the FoodData Central platform and the legacy Food Composition Database generated nearly 20 million pageviews and more than 2.7 million user sessions in FY 2020.**

Global document delivery and interlibrary loan services continue throughout the pandemic. NAL continued to provide document delivery and interlibrary loan services during the pandemic to other libraries across the United States and around the world, reaching 8,600 document deliveries/interlibrary loans for the fiscal year. NAL joined a volunteer project sponsored by the International Federation of Library Associations to support resource sharing to relieve library service disruptions caused by the pandemic. NAL emerged as a Top Ten worldwide supplier of content in July 2020.

Expanding public access to scholarly literature and research data. PubAg (www.pubag.nal.usda.gov/) is the NAL search system for USDA-funded agricultural literature. In FY 2020, NAL increased the full-text corpus publicly accessible through PubAg by nearly 88,000 articles, totaling more than 300,000 articles. Ag Data Commons (www.data.nal.usda.gov/) is a Federal research data catalog and repository that promotes the sharing and discovery of USDA-funded research data. FY 2020 improvements increased data submitters by 20 percent and increased the number of datasets cataloged and downloaded.

Digitizing historical agricultural research information and delivering it online in an easy-to-discover manner. To make the content of the world's largest agricultural library more accessible, NAL is digitizing its physical collections not under copyright protection. In FY 2020, NAL digitized and created citation information for 11,778 items (455,555 pages), bringing the total number of digitized items to 172,763 (8,147,629 pages). Until all mass-digitized publications are migrated to NAL web services, public access is available at www.archive.org/details/usdanationalagriculturallibrary.

TOP 2020 RESEARCH ACCOMPLISHMENTS

PART 3. HOW ARS DOES IT: PRIORITIZING ANIMAL, HUMAN, PLANT, AND ENVIRONMENTAL HEALTH

FOR MORE INFORMATION: www.ars.usda.gov/Protecting-Animal-Health-through-Disease-Detection-Prevention-and-Control/

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. With support from the ARS Office of International Research Engagement and Cooperation, ARS leads and coordinates global alliances to prevent, control, and—when possible—eradicate diseases such as foot-and-mouth disease and African swine fever. The following accomplishments highlight ARS advances in animal health research in FY 2020.

Development of a safe and effective African swine fever virus vaccine. African swine fever (ASF) is a devastating and highly lethal disease of pigs for which there are no commercial vaccines. The most recent vaccine candidate, ASFV-G-delta I177L, exceeded the performance of other ASF vaccine candidates. A low dose of the vaccine fully protected pigs against ASF and had no adverse effects. A patent has been issued covering the development ASFV-G-delta I177L, and ARS scientists have established an agreement to initiate the commercial development of the vaccine.

> **A low dose of the vaccine fully protected pigs against ASF and had no adverse effects.**

Predicting susceptibility of different species to infection with SARS-CoV-2. Several groups report that SARS-CoV-2, the virus that causes COVID-19, primarily enters cells by attaching to the ACE2 receptor. ARS researchers in Ames, Iowa, evaluated cross-species ACE2 genetic diversity to determine different animal species' susceptibility to SARS-CoV-2. The analysis predicted the limited potential of livestock transmission of SARS-CoV-2 and showed that genetic changes in the ACE2 receptors in domestic animals, including dogs, pigs, cattle, and goats, may have limited SARS-CoV-2 infections in these animals.

Duration of foot-and-mouth disease contagion in infected live pigs and carcasses. ARS scientists in Orient Point, New York, found that pigs infected with foot-and-mouth disease virus (FMDV) are infectious for at least 9 days—considerably longer than suggested by previous research conducted with cattle. Their research further emphasized that infected carcasses can be a potential source of FMDV contamination and must be handled properly to prevent transmission. This information can be used to update models used for foot-and-mouth disease outbreak simulations involving areas of substantial pig production.

Validation of an international standard for testing bovine tuberculosis. ARS scientists in Ames, Iowa, worked internationally with other bovine tuberculosis research labs and the World Organization for Animal Health to evaluate and validate a new international standard tuberculin for skin testing cattle for bovine tuberculosis. This new standard enables uniform testing worldwide and will benefit regulatory agencies, veterinarians, and livestock producers involved with maintaining the tuberculosis-free status of the United States.

FOR MORE INFORMATION: www.ars.usda.gov/Optimizing-Agricultural-Management-to-Mitigate-Climate-Change-Impacts/

OPTIMIZING AGRICULTURAL MANAGEMENT TO MITIGATE CLIMATE CHANGE IMPACTS

ARS climate change research builds the science-based foundations for mitigating greenhouse gas emissions, reducing the effects of climate change on production, and helping to create adaptive and resilient production systems. Through transdisciplinary research approaches that integrate information and technology, ARS provides producers with options for increasing the sustainability of their production systems. The following FY 2020 accomplishments highlight ARS advances in developing new management approaches and decision support tools to reduce agriculture's carbon footprint and boost regional farmer incomes.

Managing Midwest dairy forage production systems to reduce carbon emissions. ARS researchers in Saint Paul, Minnesota, monitored carbon balances for 9 years on a large dairy. They found that, to achieve a net gain in carbon soil storage under alfalfa-corn silage production with conventional tillage and inputs of liquid dairy manure, more than 70 percent of the carbon removed from harvested corn or more than 30 percent from harvested alfalfa would have to be returned to fields. These findings will help develop decision aids to help dairy producers evaluate whole-farm tradeoffs in carbon management.

Reducing cattle methane emissions through altered diets. Researchers are investigating ways to reduce the methane that cattle produce as a natural byproduct of digestion. ARS scientists in Texas and Oklahoma found that cattle fed a high-quality hay diet produced less methane than when fed low-quality hay. ARS researchers in Texas and Iowa also showed that adding tannin-rich peanut skin, a common regional byproduct, to cattle diets can suppress methane production. This research identifies avenues for cost-effective mitigation of methane production from beef and dairy cattle.

Reducing our carbon footprint with renewable fuels. ARS researchers in University Park, Pennsylvania, showed that ethanol could be produced from barley with a carbon footprint less than half that of gasoline. ARS scientists in Mandan, North Dakota, and collaborators demonstrated that growing oilseeds in place of fallow in non-irrigated areas of the U.S. Great Plains reduces greenhouse gas emissions and could boost regional farmer incomes from $127 million to $152 million per year through jet fuel production. These results hold promise for farmers to diversify incomes through emerging renewable fuel markets.

> **"Growing oilseeds in place of fallow in non-irrigated areas of the U.S. Great Plains reduces greenhouse gas emissions and could boost regional farmer incomes from $127 million to $152 million per year through jet fuel production."**

Decision tools to improve farm productivity and control greenhouse gas (GHG) emissions. ARS researchers in Fort Collins, Colorado, and university collaborators upgraded the DayCent model, which simulates carbon and nitrogen fluxes among the atmosphere, vegetation, and soil, to account for the effects of soil freeze-thaw and cover crops on GHGs. ARS researchers partnered with the American Farmland Trust to develop the CaRPE tool to relate crop and grazing land data with GHG emission data from DayCent. These tools will provide better estimates of and strategies to control GHG emissions.

FOR MORE INFORMATION: www.ars.usda.gov/Safeguarding-the-Food-Supply/

SAFEGUARDING THE FOOD SUPPLY

The ARS food safety research program ensures a safe food supply that meets foreign and domestic regulatory requirements. Emerging research areas focus on metagenomics, climate change and mycotoxin contamination, food adulteration and fraud, reducing foodborne pathogens during animal and crop production and food processing, and contamination of ready-to-eat foods. The following accomplishments highlight ARS advances in food safety research in FY 2020.

A novel strategy for estimating *Salmonella* contamination levels in raw ground beef. *Salmonella* is a leading cause of foodborne illness worldwide, and currently available testing methods only indicate presence or absence of *Salmonella*—they do not measure contamination levels in a tested product. ARS scientists in Clay Center, Nebraska, developed a novel strategy for rapidly estimating *Salmonella* contamination levels in raw ground beef. This new method will enable meat companies to improve their process controls, increase the safety of beef, and decrease the incidence of *Salmonella* poisoning.

A rapid test for masked toxins in wheat. Trichothecenes are fungal toxins (mycotoxins) that are toxic to humans and can contaminate oat, wheat, barley, and corn. Plants can protect themselves from trichothecenes by converting the toxins to "masked" mycotoxins, but these masked mycotoxins are still toxic to humans and are difficult for researchers to detect. ARS scientists in Peoria, Illinois, in collaboration with researchers in Bari, Italy, developed a new method to detect trichothecenes and masked mycotoxins in wheat. This rapid, sensitive, and convenient method will reduce contaminated products from the food supply.

New smartphone-based food safety spectrometer. Industry and regulatory inspectors monitor products for safety throughout food processing and production. Many food safety assays require expensive equipment found only in centralized laboratories, making it difficult to efficiently and effectively screen for contaminants. ARS-funded scientists at Purdue University have developed a $200 smartphone-based spectrometer for conducting many types of food safety assays. Inspectors can use this device at the point the sample is taken, simplifying the process and reducing the time required to obtain results.

Updated method to analyze contaminants in foods. In 2003, ARS developed a method to analyze pesticide residues in foods that has since become the worldwide gold standard. ARS scientists in Wyndmoor, Pennsylvania, have now developed an updated "quick, easy, cheap, effective, rugged, safe, efficient, and robust" (QuEChERSER) mega-method to analyze pesticides, veterinary drugs, and environmental contaminants in foods including fruits, vegetables, fish, and bovine and hemp products. QuEChERSER is expected to become the primary method used internationally for monitoring chemical contaminants in foods.

"QuEChERSER is expected to become the primary method used internationally for monitoring chemical contaminants in foods."

FOR MORE INFORMATION: www.ars.usda.gov/Protecting-Human-and-Animal-Health-by-Mitigating-the-Spread-of-Viruses/

PROTECTING HUMAN AND ANIMAL HEALTH BY MITIGATING THE SPREAD OF VIRUSES

ARS research informs and provides solutions to improve the U.S. biodefense posture, a cross-cutting issue for both agriculture and public health. 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. The following FY 2020 accomplishments highlight multidisciplinary efforts across ARS to prevent, mitigate, and respond to the spread of viruses.

COVID antiviral cotton facemasks. ARS researchers in New Orleans, Louisiana, in collaboration with a medical trauma wound dressing company, jointly developed a nonwoven cotton product demonstrated to exhibit antiviral activity. The product exhibited 99.999 percent antiviral activity after 1 hour of contact with SARS-CoV-2, the virus that causes COVID-19. Nonwoven cotton will be studied with collaborators to determine its ability to inhibit SARS-CoV-2. Following testing by a secondary company to obtain a Food and Drug Administration-approved International Organization for Standardization test for antiviral textiles, the company plans to develop a prototype for use in facemasks.

> **The facemasks exhibited 99.999 percent antiviral activity after 1 hour of contact with SARS-CoV-2, the virus that causes COVID-19.**

Integrated West Nile virus (WNV) early warning surveillance system developed. ARS scientists in Greece associated with the European Biological Control Laboratory designed an integrated WNV early warning surveillance system specifically targeting the L2 strains of WNV, a strain typically found in sub-Saharan Africa that was recently found in Europe and holds potential for invading North America. The surveillance system was successfully implemented and allowed for targeted and proactive vector control interventions, reducing this emerging threat.

Under-the-radar dengue virus infections in natural populations of *Aedes aegypti* mosquitoes. ARS researchers in Stoneville, Mississippi, have demonstrated the ability to monitor vector-borne diseases ahead of outbreaks using metagenomics and have helped identify dengue virus prior to any human infection. To date, the U.S. public health system's response to outbreaks has been largely reactive, but this research shows that by monitoring mosquito populations, it may be possible to identify emerging mosquito-borne diseases and enable proactive, targeted vector control before outbreaks occur.

Venereal transmission of vesicular stomatitis virus in biting midges. Biting midges transmit vesicular stomatitis virus (VSV) to cattle, horses, and swine. ARS scientists in Manhattan, Kansas, and Kansas State University collaborators investigated whether the virus can be maintained in insect populations in multi-year outbreaks. They found that, during mating, VSV-infected female midges could transmit virus to uninfected naïve males that had never been exposed to the virus and vice versa. This alternative route of transmission is the first evidence for venereal transmission of VSV in any known vector species.

FOR MORE INFORMATION: www.ars.usda.gov/Combating-Antimicrobial-Resistance/

COMBATING ANTIMICROBIAL RESISTANCE

ARS research elucidates the factors associated with antimicrobial resistance (AMR) in agricultural settings and develops tools and alternatives to antibiotics that mitigate AMR for the benefit of human, animal, and ecosystem health. Antimicrobials such as antibiotics will remain an essential tool for treating animal and human diseases, though the growing prevalence of resistant bacteria has garnered global concerns over the prudent use of antibiotics in animals. The following FY 2020 accomplishments highlight ARS advances in optimizing the use of and reducing the need for antibiotics in agriculture.

Prevalence of mobile colistin resistance in U.S. animal-origin food. Colistin is a last-resort antibiotic against drug-resistant Gram-negative bacterial infections. Recently, researchers discovered a mobile colistin resistance gene, mcr-1, in clinical and animal samples. ARS researchers in Albany, California, screened more than 5,000 domestic food samples and found a very low prevalence (0.02 percent) of the mcr-1 gene in tested samples. This study was the first large-scale investigation of mobile colistin resistance in U.S. food animal products, and the information will be important for trade-related food safety risk assessments.

House flies collected in agricultural settings carry antimicrobial-resistant bacteria. Adult flies ingest and may spread bacteria during feeding and reproduction, posing risks to humans and animals in their immediate environment. ARS scientists in Manhattan, Kansas, investigated microbes carried by house flies in an agricultural setting and tested their susceptibility to 14 antimicrobials. Thirty-six of 38 microbial isolates were resistant to more than one antimicrobial, and 33 were multidrug-resistant. These results emphasize the role flies may play in harboring and disseminating AMR bacteria.

New economical and efficient strategy to remove antibiotics from wastewater. An ARS researcher in Riverside, California, and collaborators at the University of California, Riverside, designed and tested a system for removing antibiotic compounds from wastewater. The overall removal efficiencies of four tested antibiotics—amoxicillin, cefalexin, sulfadiazine, and tetracycline—were 81, 91, 51, and 98 percent, respectively. These results suggest this lab-scale proof of concept system for removing antibiotics from wastewater has the potential to be scaled up for broader use.

> **“The systems’ overall removal efficiencies for four tested antibiotics—amoxicillin, cefalexin, sulfadiazine, and tetracycline—were 81, 91, 51, and 98 percent, respectively.”**

Novel antibiotic-producing bacteria discovered on squid eggs. An ARS scientist in Peoria, Illinois, together with university collaborators, characterized several antimicrobial compounds produced by bacteria in the jelly coat of squid eggs. These antimicrobial compounds prevent overgrowth by fungi and other microorganisms on the eggs. The researchers found that multiple bacteria associated with the eggs, and chemical extracts of those bacteria, inhibited growth of the pathogenic mold *Fusarium keratoplasticum* and yeast *Candida albicans*. These compounds hold promise as alternatives to traditional antibiotics.

FOR MORE INFORMATION: www.ars.usda.gov/Combating-Citrus-Greening-Disease/

COMBATING CITRUS GREENING DISEASE

ARS combats citrus greening disease through disease detection, prevention, and mitigation research. Citrus greening represents the greatest threat to the $3.35 billion U.S. citrus industry. It is caused by a bacterial pathogen, *Candidatus* Liberibacter asiaticus (CLas), which is spread by the Asian citrus psyllid. Since the psyllid's discovery in Florida in 1998, the industry has lost 60 percent of acreage and closed about 80 percent of juice plants and packinghouses. The disease has spread to Texas, California, Georgia, Arizona, and Louisiana. The following ARS advancements in FY 2020 highlight ongoing citrus greening response efforts.

New approach to solving crop pest and pathogen problems. ARS researchers in Fort Pierce, Florida, and an industry partner developed a method of attaching cells to plants; the cells deliver protective molecules in a targeted manner so that the harvested fruit or nut is not genetically engineered. Scientists have completed a proof-of-concept to protect tomato from whitefly-mediated diseases and are now evaluating this method for curing trees infected with citrus greening. This strategy holds promise for rapidly protecting plants in an environmentally sustainable method acceptable to consumers.

Enhanced detection of bacteria associated with citrus greening. ARS scientists in Beltsville, Maryland, developed a novel set of assays based on antibodies that recognize the citrus greening pathogen when it is pressed on a paper-like surface. The sensitive assay produces colored spots and is easily scaled to large numbers of samples. This simple method matches the current urgent need for accurate, sensitive, and high-throughput screening of citrus greening and holds promise for plant inspection and quarantine programs.

> **"This simple method matches the current urgent need for accurate, sensitive, and high-throughput screening of citrus greening and holds promise for plant inspection and quarantine programs."**

Molecular profiling of citrus leaves. ARS scientists in Ithaca, New York, and Riverside, California, documented that lemon and navel orange trees infected with the citrus greening bacterium exhibited certain molecular changes. Molecular profiles began changing months before visual symptoms of disease appeared, demonstrating the utility of molecular profiling for early detection of citrus greening disease. Results from this study reveal differences in the response to infection between these two distinct varieties of citrus and can be used to improve diagnostic tests for citrus greening disease.

A strategy to control Asian citrus psyllid. Growers rely on insecticides to control Asian citrus psyllid, but insecticide-resistant psyllid populations are evolving and control costs are high. As an alternative to insecticide control, ARS researchers in Fort Pierce, Florida, are developing a "Conservation Biological Control" strategy that involves growing certain plants to support populations of insect predators that attack the psyllid. The researchers are using statistical modeling to optimize proportions of crown-of-thorn, lima beans, wild poinsettia, flowering buckwheat, partridge pea, and ornamental portulaca to aid in biological control of the psyllid.

FOR MORE INFORMATION: www.ars.usda.gov/Protecting-Pollinator-Health/

PROTECTING POLLINATOR HEALTH

ARS promotes sustainable crop production by protecting crops and pollinators from pests that threaten their health and consequently reduce crop yields. More than 4,500 invasive pests damage crops, costing U.S. agriculture an estimated $30 billion annually. In addition, the risks posed to bees by invasive mites, beetles, and disease is equivalent to $15 billion in lost pollination services for fruit, nut (almond), and legume crops. The following FY 2020 accomplishments highlight several ARS advances in pollinator health and pest management research.

Spirulina as a promising nutritional supplement for honeybees. Beekeepers commonly feed honeybees artificial substitute diets to support colony health during periods of reduced forage, but these diets may be deficient in essential macronutrients. ARS researchers in Baton Rouge, Louisiana, found that the microalga spirulina is rich in many of the same macronutrients commonly found in pollen and that bees fed spirulina had similar markers of nutritional status compared to bees fed a natural pollen diet. Spirulina therefore shows promise as a pollen substitute or prebiotic diet additive to improve honeybee health.

Access to U.S. Conservation Reserve Program (CRP) lands greatly improves honey bee colony health. The honey bee nutritional landscape is critical to the sustainability of commercial beekeeping and modern agriculture, but these landscapes are diminishing rapidly. ARS researchers in Tucson, Arizona, found that colonies with access to CRP landscapes showed markedly improved size, performance, and function (including disease resistance) compared to intensively cultivated landscapes. The study validates the overwhelming utility of U.S. conservation lands in protecting pollinator health.

> **The study validates the overwhelming utility of U.S. conservation lands in protecting pollinator health.**

Centipedegrass lawns support numerous bee species. Centipedegrass is a warm season turfgrass often grown in the southeastern United States. To understand the role of centipedegrass in supporting pollinators, ARS researchers in Tifton, Georgia, and scientists from the University of Georgia surveyed bees in centipedegrass lawns in central and southern Georgia. The study documented numerous bee species residing and foraging in and around these lawns. Landscape managers should therefore be conservative in applying insecticides to centipedegrass lawns, since some insecticides are toxic to bees.

Impact of climate change on alpine bee communities. To understand the impact of climate change on alpine bees, ARS scientists in Logan, Utah, conducted a 9-year study of bees in the Colorado Rocky Mountains. Periodic events in the bee life cycle (phenology) were less sensitive to climatic variation than flower phenology, potentially reducing seasonal synchronizations between flowers and pollinators. Interestingly, alpine bee diversity and population size increased in locations with large-scale bark beetle outbreaks, where dead trees promote greater diversity and number of flowers in the open canopy.

FOR MORE INFORMATION: www.ars.usda.gov/Optimizing-Agricultural-Water-Use-and-Management/

OPTIMIZING AGRICULTURAL WATER USE AND MANAGEMENT

The ARS Watershed and Water Availability research program develops solutions that improve water management for efficient agricultural production. In the United States, irrigated agriculture produces 49 percent of U.S. crop market value on 18 percent of cropped lands. However, agriculture is subject to growing competition for water resources, growing pressure to safeguard water quality, and a clear need to adapt to alternative water resources. The following FY 2020 research accomplishments highlight ARS advancements in irrigation, drainage technology, and decision support systems for addressing the challenges associated with agricultural water use.

Sub-surface drip irrigation reduces seasonal irrigation applications for corn. In the face of declining water supplies, crop farmers need to maximize the yield per unit of water used in crop production. ARS scientists in Bushland, Texas, found that subsurface drip irrigation (SDI) in grain corn reduced water loss to evaporation by 2 to 5 inches during the growing season compared to losses that occurred with sprinkler irrigation. SDI also reduced overall corn water use by up to 6 inches and increased grain yields by up to 20 percent. These benefits are enough to offset the higher costs for SDI installation.

Deficit irrigation saves water in peach production under arid conditions. Deficit irrigation—which involves irrigating crops only at drought-sensitive stages of growth—is a potential strategy to save water in arid and semiarid regions of the world without severely impacting crop production. ARS researchers in Parlier, California, demonstrated in a 10-year peach production field study that deficit irrigation can result in up to 40 percent water savings without significant yield losses or reductions in fruit quality. Findings from this study provide peach growers an alternative irrigation strategy to save water and lower input costs.

A long-term solution for thirsty crops. Polymer hydrogels increase the capacity of soil to hold water to support plants in water limited environments. ARS researchers in Kimberly, Idaho, studied the impact of hydrogels on soil water availability over a 9-year study. The researchers observed a slow decline in water availability and extrapolated that hydrogels could provide water retention benefits lasting 24 to 29 years—considerably longer than current industry estimates. These long-term benefits substantially increase the cost effectiveness for farmers applying hydrogels to improve soil's water holding capacity.

> **"Hydrogels could provide water retention benefits lasting 24 to 29 years—considerably longer than current industry estimates."**

Inexpensive, accurate sensors for optimizing irrigation. Research conducted by ARS scientists in Bushland, Texas, demonstrated that irrigation scheduling based on center pivot temperature sensors are as accurate as stationary sensors mounted on crop leaves, alleviating previous concerns about the accuracy of center pivot sensors. Center pivots are now used on 30 million acres in the United States. Installing temperature sensors aboard center pivots and using them for irrigation scheduling could save farmers substantial water and reduce energy input costs.

FOR MORE INFORMATION: www.ars.usda.gov/Monitoring-and-Mitigating-the-Spread-of-Plant-Disease/

MONITORING AND MITIGATING THE SPREAD OF PLANT DISEASE

ARS is committed to controlling plant diseases to protect our food security and ensure an adequate supply of non-food crops for feed, fiber, energy, and horticultural uses. Plant diseases have significant impacts on yields and quality, resulting in billions of dollars in economic losses and management inputs each year to crops, landscapes, and forests in the United States. Effective control of plant diseases requires an understanding of the biology of disease-causing agents. The following FY 2020 accomplishments highlight ARS successes in identifying and studying the spread of plant diseases.

Predicting the spread of two severe citrus diseases by hurricanes. Asiatic citrus canker (ACC) and citrus black spot (CBS) are severe impediments to international trade of citrus. ARS researchers in Fort Pierce, Florida, adapted a previously developed model to predict where the 2017 Hurricane Harvey (in southeast Texas) and Hurricane Irma (in southwest Florida) may have spread ACC and CBS, respectively. Regulatory agencies and advisory committees in Florida and Texas have since partnered with the USDA Animal and Plant Health Inspection Service to deploy surveys for early detection of these diseases in both states.

Identification and movement of a nematode causing beech leaf disease (BLD) in North America. ARS researchers in Beltsville, Maryland, and collaborators identified and described a new subspecies of foliar plant-parasitic nematodes found in leaves of beech trees near Cleveland, Ohio. This nematode, which transmits BLD, is of international concern because it is a suspected invasive species from Asia, where it causes relatively minor damage. These results are important to pathologists, arborists, and regulators of domestic and international trade who want to contain this nematode and reduce its destruction.

New bacterial plant pathogen of onions. Onion production in New York is valued at more than $39 million. Losses due to bacterial diseases can be up to 75 percent in infected fields. There are currently no pesticides that are effective on bacterial rots. ARS scientists in Ithaca, New York, discovered a new bacterium species responsible for an onion disease in New York state that was not previously known to exist in the United States. This information is useful for USDA's Animal and Plant Health Inspection Service for monitoring the introduction and spread of plant disease-causing bacteria in the United States.

ARS scientists in Ithaca, New York, discovered a new bacterium species responsible for an onion disease in New York state that was not previously known to exist in the United States.

First report of grapevine red blotch virus in Idaho. ARS scientists in Parma, Idaho, in collaboration with University of Idaho and commercial grape growers, documented the presence of grapevine red blotch virus (GRBV) in Idaho commercial vineyards. The disease may delay fruit ripening and therefore reduce wine quality for some varieties in some regions. GRBV had not been previously reported in commercial Idaho vineyards. Multiple years of sampling and testing for GRBV in Idaho indicate limited spread. The grape industry can use these findings for making vineyard replanting decisions.

FOR MORE INFORMATION: www.ars.usda.gov/Controlling-Insect-Pests-to-Protect-Plant-Animal-and-Human-Health/

CONTROLLING INSECT PESTS TO PROTECT PLANT, ANIMAL, AND HUMAN HEALTH

ARS collaborates across the human, animal, and environmental health communities to achieve sustained health outcomes for plants, animals, and people. Research at ARS informs and provides solutions to improve the U.S. biodefense posture and encompasses animal health; medical, veterinary, and urban entomology; plant health; and natural resources and sustainable agricultural systems. The following FY 2020 accomplishments illustrate ARS efforts to eliminate arthropod vectors and nullify their impacts.

New and quick method to identify cattle fever ticks resistant to pyrethroids. ARS scientists in Kerrville and Edinburg, Texas, and Pullman, Washington, and collaborators at Northern Arizona University and the University of Queretaro (Mexico) developed a new and quick method to identify cattle fever ticks resistant to pyrethroids. This molecular assay can be completed overnight while the traditional bioassay method takes 6 weeks to complete. The ability to quickly detect pyrethroid-resistant ticks enables selection of the proper pesticide to use on wildlife to prevent the spread of fever ticks to cattle during outbreaks.

Ag100Pest project opens new opportunities for invasive pest control. The Ag100 Pest Initiative, led by ARS, develops high quality reference genome assemblies for the top 100 U.S. arthropod agricultural pests. These genomic resources are critical for the development of biobased tools for biosecurity. In FY 2020, the Ag100 Pest Initiative sequenced the complete genome of the Asian giant hornet, a deadly predator of honeybees first spotted in North America in 2020. The initiative has also sequenced the first genome of spotted lanternfly, an invasive pest of hardwoods and several specialty crops.

> **The Ag100 Pest Initiative sequenced the complete genome of the Asian giant hornet, a deadly predator of honeybees first spotted in North America in 2020.**

Environmental temperature affects the ability of mosquitoes to transmit Rift Valley fever virus (RVFV). In a study of two mosquito species, ARS researchers in Manhattan, Kansas, and collaborators at the U.S. Army Medical Research Institute for Infectious Diseases found that increased temperature was associated with increased potential for mosquitoes to transmit RVFV as well as more rapid and efficient infections. These data on the effects of ambient temperature facilitate development of more accurate models to assess RVFV persistence and spread in nature should a disease outbreak ever occur in the United States.

Pesticide-resistant mosquitoes pose challenges to protecting military. ARS researchers in Gainesville, Florida, and U.S. Department of Defense collaborating scientists found that permethrin-treated military uniforms may be ineffective against pyrethroid-resistant strains of *Aedes aegypti*, a vector of numerous human diseases. Fortunately, they found that DEET-based repellents are still effective against *Aedes aegypti* resistant to pyrethroids. This information will lead to changes in approaches used to protect at-risk military members operating in areas where pyrethroid-resistant mosquitoes exist.

FOR MORE INFORMATION: www.ars.usda.gov/Improving-Pasture-and-Rangeland-Management/

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. To support rural prosperity, food security, and healthy agroecosystems, ARS research helps producers improve management decisions and ultimately achieve healthy and productive pastures and rangelands, as illustrated by the following FY 2020 research accomplishments.

Powerful tools and techniques for monitoring rangeland production systems improve management and lower production costs. ARS scientists in Las Cruces, New Mexico, led the expansion of the rangeland monitoring program and the publication of the Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems. These resources help the Bureau of Land Management and Natural Resources Conservation Service make decisions about wildlife habitat suitability, evaluate conservation practice effectiveness, and improve grazing management systems across the continent's rangelands.

Modeling wind erosion on western U.S. grazing lands. Rangeland wind erosion reduces soil productivity and causes highway fatalities, human health problems, and infrastructure damage across western U.S. grazing lands. ARS scientists in Las Cruces, New Mexico, adapted the Aeolian Erosion model to assess rangeland wind erosion across plot to regional scales. The model is based on data collected in real time at the 15 National Wind Erosion Research Network sites and makes it possible to model the effects of rangeland management practices on wind erosion to mitigate this problem in the future.

"The model is based on data collected in real time at the 15 National Wind Erosion Research Network sites and makes it possible to model the effects of rangeland management practices on wind erosion to mitigate this problem in the future."

Grass-Cast Decision Support tool now available for U.S. Southwest and entire Great Plains. Ranchers must decide yearly whether the forage available on their land is sufficient to support their livestock without impairing the future productivity of the land. ARS scientists in Wyoming and Colorado and collaborators developed Grass-Cast (grasscast.unl.edu) to forecast forage production for rangelands across the entire Great Plains, New Mexico, and Arizona. Livestock producers have great interest in seeing Grass-Cast expanded to the U.S. Great Basin, California, and Canadian prairies.

Management practices that improve rangeland restoration after wildfire. On average, the Bureau of Land Management spends more than $35 million per year on post-fire rehabilitation treatments to reduce annual grass invasion and re-establish native communities that are resilient to future wildfire. ARS scientists in Reno, Nevada, found that the number of wildfire events was reduced when drill seeding was used instead of aerial seeding. Additionally, these scientists and other ARS and university collaborators found that diverse assemblages of native grasses reduce invasion by exotic annual grass species.

Additional copies of this Report on Science can be downloaded from **www.ars.usda.gov.**

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