



United States Department of Agriculture

# FY 2016 Annual Report on Technology Transfer

The collage features four distinct images. The top-left image shows a field researcher in an orange vest and blue gloves examining a tree trunk, while another person in the background takes notes. The top-right image is a line graph titled 'Corn Acres United States' showing 'Planted' (blue line) and 'Harvested' (red line) acres from 1996 to 2016. The bottom-left image shows two close-up views of a reddish-brown tick. The bottom-right image shows a black and white cow standing in a field of yellow wildflowers.

Year	Planted	Harvested
1996	79	73
1997	79	73
1998	79	73
1999	78	72
2000	79	72
2001	76	70
2002	78	69
2003	78	70
2004	81	74
2005	80	71
2006	93	86
2007	86	79
2008	86	79
2009	88	81
2010	92	84
2011	96	87
2012	95	87
2013	90	83
2014	87	81
2015	94	86
2016	94	86

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## **INTRODUCTION**

President Abraham Lincoln coined the phrase “the People’s Department” acknowledging the role of the Department of Agriculture in solving problems that benefits all people every day. Thus, well before the coining of the modern day phrase of “technology transfer,” it was the culture of USDA to deliver solutions to the people of the United States. Today, USDA broadly defines technology transfer as the adoption of research outcomes (i.e., solutions) for public benefit. A seemingly simple statement, the process of adoption is complicated, requiring integration of many assets from disparate sources in the successful delivery of solutions. “Public benefit” is achieved through many mechanisms including public release of information, tools, and solutions (e.g., germplasm, plants and other materials), adoption and enhancement of research outcomes by partners through collaborative research, formal cooperative research and development agreements (CRADA) authorized by the Federal Technology Transfer Act (1986), direct Federal, State, or local technical assistance, or through licensing of biological materials or protected intellectual property directly to not-for-profit entities and for-profit private sector firms. Additionally, successful adoption of USDA knowledge and research outcomes typically requires complementary assets and services provided by multiple agencies in USDA, including agencies that are not primarily engaged in direct research in the physical and life science arenas.

Private sector involvement in technology transfer adds the benefits of creating new or expanded businesses, jobs, and economic prosperity. Science-based innovations from USDA intramural research, often developed through public-private partnerships (PPPs), create new or improved technologies, processes, products and services that benefit the Nation by increasing productivity, increasing efficiency (keeping costs low), and enhancing global competitiveness for the U.S. agriculture sector. Thus,

technology-transfer functions are critical to accelerating utility of public research and development investments, creating economic activity, and in job creation and sustainable economic development.

The Agricultural Research Service (ARS) has been delegated authority by the Secretary of Agriculture to administer the patent program for ARS, and to review CRADAs and administer technology licensing programs for all intramural research conducted by USDA. These activities are housed in the Office of Technology Transfer.

On October 28, 2011, following a series of reports identifying the status of technology transfer from Federal funds and Federal laboratories, the White House issued the Presidential Memorandum – “Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Businesses.” Issuance of this Memorandum provided an unprecedented opportunity for unifying technology transfer across USDA science and technology agencies as the mechanism to deliver these outcomes for public good. In the USDA’s response to the Presidential Memorandum (<http://www.nist.gov/tpo/publications/upload/USDA-Tech-Transfer-Plan.pdf>), several initiatives were identified to promote technology transfer and commercialization. These initiatives ushered in a new era of unprecedented collaboration among agencies of USDA to enhance services and opportunities to the customers and stakeholders of the Department. This report describes progress in implementing these initiatives.

This report also covers technology-transfer activities and metrics for the USDA Agricultural Marketing Service (AMS), Animal and Plant Health Inspection Service (APHIS), Agricultural Research Service (ARS), Economic Research Service (ERS), Foreign Agricultural Service (FAS), Food Safety and Inspection

Service (FSIS), Forest Service (FS), Grain Inspection, Packers and Stockyards Administration (GIPSA), National Agricultural Statistics Service (NASS), National Institute of Food and Agriculture (NIFA), and Natural Resources Conservation Service (NRCS).

## COMBINED METRIC TABLES FOR ALL USDA AGENCIES

**Table 1: Invention Disclosures and Patents from APHIS, ARS, and FS.**

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
<b>Invention Disclosures</b>					
Number of new inventions disclosed	160	191	117	222	244
<b>Patents</b>					
Number of patent applications filed	122	157	119	125	109
Number of patents received	69	65	83	94	60

**Table 2: Active Licenses from APHIS, ARS, and FS.**

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
<b>Total Active Licenses</b>	384	400	414	424	441
To small business	119	139	154	150	152
To startups	ND	13	13	13	7
Invention licenses	341	351	363	359	370
<b>Total New Licenses</b>	34	25	30	35	33
Invention licenses	28	19	28	20	27
<b>Income Bearing Licenses, Total</b>	379	397	412	421	439
Exclusive licenses	277	291	299	292	307
Partially exclusive licenses	14	13	15	11	9
Non-exclusive licenses	88	93	98	118	120

**Table 3: Elapsed Amount of Time for Granting Licenses and Licensing Income from ARS\*.**

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
<b>Elapsed Amount of Time for Granting Licenses</b>					
Average (months)	5.8	3.5	5.9	2.8	4.9
Minimum (months)	0.3	0.4	0.9	0.5	0.9
Maximum (months)	19.7	12.5	21.5	10.0	16.0
<b>License income</b>					
Total active licenses	\$3,806,164	\$4,385,952	\$4,927,938	\$5,066,988	\$4,784,466
Total invention license	\$3,670,692	\$4,053,931	\$4,733,200	\$4,842,256	\$4,456,054
<b>Earned Royalty Income</b>	\$3,059,989	\$3,353,876	\$3,610,774	\$3,509,904	\$3,633,239
Earned Royalty Income from top 1% of licenses	N/R	N/R	N/R	N/R	N/R

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Earned Royalty Income from top 5% of licenses	\$1,752,367	\$1,969,155	\$2,048,317	\$1,756,460	\$1,811,637
Earned Royalty Income from top 20% of licenses	\$2,604,008	\$2,892,796	\$3,103,143	\$2,856,924	\$3,043,395
Minimum Earned Royalty Income	\$44	\$5	\$32	\$13	\$5
Maximum Earned Royalty Income	\$757,219	\$856,987	\$575,753	\$728,017	\$818,537
Median Earned Royalty Income	\$5,000	\$3,609	\$3,232	\$3,525	\$3,966
<b>Disposition of Earned Royalty Income</b>					
Percent of Earned Royalty Income distributed to inventors	25%	25%	25%	25%	25%
Percent of Earned Royalty Income distributed to the agency or laboratory	0%	0%	0%	0%	0%
Licenses terminated for cause	0	0	0	0	0

\*Only ARS numbers are reported due to the low numbers of AHIS and FS licenses and their generated income. N/R, data is not reported due to its proprietary nature.

**Table 4: Collaborative research agreements from APHIS, FS and ARS.**

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
<b>Total Active CRADAs</b>	274	259	267	301	238
With small businesses	130	117	102	106	76
Traditional CRADAs	211	211	193	188	161
Non-traditional CRADAs	63	48	74	113	77
<b>Total Newly Executed CRADAs</b>	65	86	60	80	79
With small businesses				32	14
Traditional CRADAs	45	54	39	52	43
Non-traditional CRADAs	14	21	21	28	36
<b>Total other collaborative R&amp;D Agreements<sup>1</sup></b>	14,691	16,199	16,144	14,206	11,854
<b>Newly executed other collaborative R&amp;D Agreements</b>	1182	3255	2656	2489	3288

<sup>1</sup>Includes Trust Fund Cooperative Agreements, Reimbursable Agreements, Material Transfer Research Agreements, Specific Cooperative Agreements and Non-Funded Cooperative Agreements, Challenge Cost-Share Agreements, Collections Agreements, Cooperative Agreements, Inter-agency & Intra-agency Agreements, Joint Venture Agreements, Participating Agreements, Research Cost-Reimbursable Agreements, Research Joint Venture Agreements.

**Table 5: Small businesses, startups, and young companies.**

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Total number of small businesses supported					
Total number of startups and young companies supported					

**Response to Presidential Memorandum on Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Business**

**USDA 1: New metrics proposed for standard annual reporting in addition to those required by Circular A-11 instructions on annual reporting of technology transfer**

This initiative was completed in FY 2013 and the new metrics are now a standard component of the ARS report.

**USDA 2: Update Policy and Procedure (P&P) 141.2 “Technology Transfer in ARS”**

This initiative was completed in FY 2015 and the new P&P was issued.

**USDA 3: Expand Agricultural Research Partnership (ARP) Network efforts to extend the impact of ARS research**

This initiative was completed in FY 2014 and the metrics are now a standard component of the ARS report.

**USDA 4: Expand outreach efforts in technology transfer to scientists in ARS**

This initiative was completed in FY 2015 and standard technology transfer PowerPoint training modules are posted on AgLearn for e-training.

**USDA 5: Encourage other S&T agencies to adopt OTT's approach to technology transfer**

This initiative was completed in FY 2015 and the metrics are now a standard component of the ARS report.

**USDA 6: Explore expanded use of Enhanced Use Lease (EUL) authority as technology transfer tool to promote longer term relationships with key customer groups**

Under the 2008 Farm Bill, the Secretary was given the authority to establish a pilot project at the Beltsville Agricultural Research Center (BARC) to lease non-excess property to any private or public entities. The EUL Project was used as a technology transfer tool designed to provide longer term public-private partnerships than can be done through existing technology-transfer partnership instruments. The pilot authority was used to develop a process to identify underutilized laboratory resources that could be used by the private sector to commercialize ARS research outcomes. Prospective lessees needed to establish either a licensing partnership or research collaboration with ARS. In exchange, EUL terms provide the lessee 20 years of use of the facility to develop its business. EUL authority proved to be a very successful strategy to leverage resources for entrepreneurial activities. USDA's first lessee (Plant Sensory Systems) was a small business that in FY 2013 was awarded a \$1.8 million ARPA-E grant (Better Biofuel Feedstock from Beets) based on the success of the research project conducted using

BARC laboratory facilities. Access to these facilities was essential because this small business did not have sufficient capital to build the facilities needed for this research project.

This pilot authority for BARC was reauthorized in 2014 Farm Bill. Discussion began in FY2015 and is ongoing to identify a partner to establish an accelerator on the BARC campus for agriculture businesses that utilize ARS technologies and/or research expertise.

**USDA 7: Beginning in FY 2012 / 2013, roll out a nationwide series of regional forums to identify issues and deliver solutions**

This initiative was completed in FY 2015 and the metrics are now a standard component of the ARS report.

**USDA 8: Provide opportunities for applicants to the USDA Small Business Innovation Research (SBIR) program to partner with ARS scientists to further develop science necessary for business success**

This initiative was completed in FY 2015 and the metrics are now a standard component of the ARS report.

**USDA 9: Provide Cooperative Research and Development Agreement (CRADA) partners opportunity to link to local Manufacturing Extension Partnership (MEP) resources to assist in commercialization efforts**

This initiative was completed in FY 2015 and the metrics are now a standard component of the ARS report.

**USDA 10: Work with regional incubators and economic development organizations to identify opportunities for ARS scientists and ARS commercial partners**

This initiative was completed in FY 2015 and the metrics are now a standard component of the ARS report on the Agricultural Research Partnerships (ARP) Network.

**USDA 11: Establishment of the “Branded Food Products Database for Public Health” Public-Private Partnership**

In FY 2013, ARS, the ATIP Foundation, and the International Life Science Institute North America (ILSI North America) established a public-private partnership to enhance the public’s health through increased knowledge of the nutritional content of the nation’s food supply. This will be accomplished by obtaining comprehensive food composition data from the food industry and making it available to government, industry, the scientific community and the general public through an enhanced USDA National Nutrient Database, developed and maintained by the ARS Nutrient Data Laboratory in Beltsville, MD.

In FY 2015, the public-private partnership successfully beta tested a branded food products database. Five food manufacturers participated in a beta-test by providing product label data and nutrition information on 245 products through a GS1 certified data pool provider, FSEnet. These data were then passed to ARS for incorporation into the USDA National Nutrient Database.

In FY 2016, Secretary Tom Vilsack officially launched the USDA Branded Food Products Database, a free online resource for families, the food industry, and researchers containing nutrition details on more than 80,000 name-brand prepared and packaged foods available at restaurants and grocery stores. The new database and user-friendly interface was the result of a partnership between ARS, ILSI North America, GS1 US, 1WorldSync, and Label Insight.

**USDA 12: Evaluate various options for reducing license negotiation transaction costs**

This initiative was completed in FY 2015, and the metrics are now a standard component of the ARS report.

**USDA 13: Develop Material Transfer Research Agreement (MTRA) as a new instrument to promote development and commercialization of materials from USDA**

This initiative was completed in FY 2013, and the metrics are now a standard component of the ARS report.

**USDA 14: Accountability of scientists and engineers in technology-transfer accomplishments**

In 2012 the annual performance standards for scientist evaluations were revised to include technology transfer elements. In FY 2014, two new performance metrics, Science Delivery Products and Science Delivery Activities, were deployed to measure technology transfer performed at each station. Science Delivery Products, such as non-refereed publications, software, web, and multimedia products, enhance

the usefulness of scientific information. Science Delivery Activities, such as workshops, communicate the usefulness of scientific information to users.

Performance measure	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Science Delivery Activities	NA	NA	1,224	2,514	2,744
Science Delivery Products	NA	NA	429	442	310
Science Delivery Total	NA	NA	1,653	2,956	3,054

**USDA 15: New uniform metrics for Forest Service outcomes**

A major review of all performance metrics was conducted in FY 2014 that resulted in 10 new performance metrics, 5 existing metrics were revised, 3 metrics were retired, and 10 existing metrics were not changed. There were no additional changes to metrics during FY 2015-2016.

The “Chief’s Science Delivery Award” and the National Wilderness Award for Excellence in Wilderness Research Applications were presented in February 2016.

Forest Service periodically assesses the number of citations of scientists’ publications as an index of the impact of Forest Service science. These indices are: average number of times FS scientists’ papers are cited in Science Citation Index during the previous 10-year period beginning 2 years after publication, average annual number of high impact papers (papers cited >20 times), and average annual number of very high impact papers (papers cited >50 times). As reported by Web of Science, from 2006 through October 2015, publications authored by FS scientists were cited in peer reviewed scientific journals an average of 14,634 times/year. There were 1,945 high impact papers and 596 very high impact papers for the 10-year period ending in 2015.

**USDA 16: New metrics on research outcomes related to intellectual property (patents)**

FS R&D developed and implemented the Research Information Tracking System (RITS), which became the official FS reporting vehicle for all science publications in FY 2010. RITS improves data quality and consistency, provides transparency to the public, and reduces burdensome data calls. The newest version of RITS incorporates patent data which are connected to related publications on specific technology focus areas. Patent data in RITS have been updated to include the last 20 years of information. Going forward, patent data will be entered in RITS annually. Additional updates to improve the patent portion of RITS are planned for future releases.

**USDA 17: Explore additional ways FS and ARS can work together on intellectual property-related matters**

Cooperative Research and Development Agreements (CRADAs) are widely used within the FS to enable researchers to work with university partners and industry leaders and are drafted by the FS Grants and Agreements Specialists. Recognizing efficiencies that could be gained by having standardized agreement language and procedures, FS has used ARS as a CRADA resource in FY 2014-FY2016 to assist with CRADA questions. Further collaboration is planned for FY 2017.

**USDA 18: Enhance education and extension outreach efforts**

*Natural Inquirer* is a science education journal based on Forest Service science and written for middle school students. Expanded *Natural Inquirer* products include science journals for upper elementary students, scientist cards for middle and high school students, Readers for K-2, and an informal activity

guide for middle school students. All of these products are based directly on Forest Service scientists and their research. In FY 2016, 67,440 *Natural Inquirers*, *Investi-gators*, *Readers*, and *NSI: Nature Science Investigators* were distributed to classrooms, homeschools, and conferences. Over 100,000 scientist cards were distributed, including 65,000 women or minority cards. In total, 160 Forest Service scientists were introduced on the scientist cards. Increase in social media: Facebook: 25 percent; Twitter: 18 percent; and Pinterest: 25 percent. The *Natural Inquirer* Web site had 72,834 unique visitors in FY 2016, a 25 percent-increase over FY 2015. Noteworthy distribution points included the National Science Teachers Association; the Association for Supervision and Curriculum Development; the Women of Color in STEM Conference; the Minorities in Agriculture, Natural Resources, and Related Sciences Conference; Americas for Conservation + the Arts; the Ecological Society's Annual SEEDS Conference; and the Detroit City School System. All work is accomplished in cooperation with our non-profit partner, the Cradle of Forestry in America Interpretive Association, and the University of Georgia. <http://naturalinquirer.org>

**USDA 19: Enhance FS interactions with entrepreneurship activities at educational institutions**

FS Patent Program continued working with University of Wisconsin-Whitewater through their Small Business Development Center, in which upper class undergraduate business and entrepreneurship students enrolled in "Consulting for Entrepreneurial Companies" develop marketing plans and ideas for patented FS technologies. Each semester a single technology is investigated in-depth and a marketing report is produced. This report is shared with the FS inventors and, if applicable, joint owners for possible further action. In addition, students are encouraged to consider starting businesses based on the technologies.

FS has also continued to work with University of Wisconsin-Madison MBA students in the “Strategic Management of Innovation” class each spring semester. For this class, a variety of patented FS technologies along with patented technologies from Wisconsin Alumni Research Foundation, the patenting and licensing arm of the University of Wisconsin are presented to the class at the beginning of the semester. Students are divided into groups of 4-6 students. Each group picks one of the technologies to research and prepare a marketing report. These students are also encouraged to consider starting businesses based on the technologies.

**USDA 20: Increase awareness in WS of technology transfer mechanisms, leading to increased pace of effective technology transfer and commercialization**

WS NWRC has traditionally been active in transferring technology and scientific information through use of outreach to collaborators, including WS operational personnel and through publications. Successful outcomes may include improved wildlife damage management practices, scientific information that enhances U.S. competitiveness by protecting crops and property, or increased awareness about wildlife diseases that threaten health of livestock or humans. Most of these outcomes do not require a patent and license for implementation. This initiative is designed to increase awareness among WS personnel about the importance of both formal and informal technology transfer.

The Manager of the Technology Transfer Program provided a formal and information technology transfer training to NWRC biologists at both the headquarters and field locations, increasing the general knowledge and raising the awareness of scientists as to the power of partnerships, importance of

developing intellectual property, and the array of technology transfer agreements available to facilitate their research. In addition, WS NWRC's Technology Transfer staff continued to reach out to WS Operations on technology transfer and intellectual property issues. WS Operations staff contacted WS NWRC's Technology Transfer Program for regulatory advice on issues related to feral swine trapping, four confidentiality agreements.

WS continues to emphasize the importance of collaborative agreements with stakeholders to offset diminishing discretionary funding, while increasing relevance of research to stakeholders, such as the private sector. WS, as part of the annual report table, continues to track the number of agreements it maintains each year, including cooperative agreements, cooperative service agreements, memorandums of understanding, and interagency agreements. In addition, WS will track numbers of specific technology transfer agreements, including CAs, MTAs, MTRAs, CRADAs, invention disclosures, and patent and license activity.

During FY 2016, WS NWRC Technology Transfer staff completed 45 unique intellectual property agreements. These included 7 CAs, 18 MTAs, 7 MTRAs, and 2 CRADAs. These agreements brought more than \$683,737 in cooperator funding to the NWRC, allowing scientists to pursue collaborative research aimed at developing products to mitigate wildlife damage issues. In addition, licensing royalties received by NWRC totaled \$17,500, of which \$6,325 were disbursed to inventors, the remainder used internally to support ongoing technology transfer efforts. In total, NWRC Technology Transfer efforts accounted for more than \$701,237 in extramural funding.

In addition to traditional technology transfer mechanisms, the WS National Wildlife Research Center publishes scientific manuscripts, book chapters, and reports. In FY 2016, the NWRC released 118

publications, including 99 scientific manuscripts in peer-reviewed outlets and 8 in non-indexed outlets. Also during FY16, NWRC scientists served as editors or authors of 10 books or book chapters. NWRC also tracks Internet website traffic and publication downloads. In FY16, the NWRC website saw 143,190 publication downloads from a total for 214 countries. Website referrals were most frequent from Google, Google Scholar and Google India.

In addition to Center-wide publication efforts, the staff of the Technology Transfer Program published two peer-reviewed manuscripts and submitted two additional manuscripts for publication in non-indexed outlets and one book chapter. The Registration Unit prepared 23 EPA data submissions for registering sodium nitrite as a toxicant for feral swine. These data submissions were part of a CRADA partnership with an Australian enterprise in support of an Experimental Use Permit application to the U.S. Environmental Protection Agency for developing sodium nitrite as a toxicant for feral swine.

**USDA 21: Increase knowledge of WS and NWRC and their impact in preventing wildlife conflicts, leading to increased development of collaborative research and more effective use of public resources**

WS NWRC has committed to increasing the amount of information disseminated to the general public and stakeholders on research, collaborations and products provided by the Program. The WS NWRC works closely with APHIS public affairs staff in the preparation and dissemination of information on WS NWRC research and collaborations, as well as WS's role as the premier organization for managing human-wildlife conflicts.

As part of continued efforts to increase local and regional community awareness of the WS NWRC, in FY 2016, the Center hosted tours to approximately 240 students, visiting scientists, business and agency partners, and USDA employees. Center representatives hosted booths at several university career fairs to inform students of careers and potential job opportunities with the WS NWRC, as well as funded the development of a new overview video and 5 shorter video vignettes highlighting the Center's diverse workforce, technology transfer, and unique mission. Through the USDA's blog site, Twitter site, YouTube, and GovDelivery system, WS NWRC notified 10,000+ stakeholders of various research activities, accomplishments, and events. WS NWRC responded to 134 media and community requests for information and published approximately 20 brochures, factsheets, press releases, and reports for the general public.

**USDA 22: Increase the pace of WS technology transfer and commercialization activities**

To accomplish this objective, WS NWRC will increase its efforts to obtain partners for technologies ready to be commercialized by working with ARS and by utilizing the ATIP Program.

WS continues to maintain existing products and registering new products with the Environmental Protection Agency (EPA) and the Food and Drug Administration for use by WS personnel and the public. In FY 2016, APHIS WS maintained 24 Section 3 registrations with the Environmental Protection Agency and made 1 pesticide Experimental Use Permit (EUP) application submission, and received 1 EUP EPA exemption for a new active ingredient intended for a product to control feral swine. A total of 20 Section 24c (Special Local Need) pesticide registrations were maintained and 3 new labels were obtained; 1 Experimental Use Permit was in place. In addition, APHIS WS maintained two Investigational New Animal Drug permits with the Food and Drug Administration.

**USDA 23: Enhance collaboration efforts in pest detection and management**

PPQ's scientific support focuses on improving and developing pest detection and management tools to discover new invasive species early and respond quickly, better identify and target offshore pest threats, develop diagnostic tools and techniques, and transfer technology to cooperators and impacted industries.

**Strengthen PPQs pest exclusion system:**

- Completed analysis of three molecular diagnostic pilots at four PPQ Plant Inspection Stations to evaluate the use of molecular diagnostics at Plant Inspection Stations. A Molecular Diagnostics Working Group (MDWG) was formed and began developing a framework for implementing molecular diagnostic to support plant inspections at Ports of Entry. A team is being established to lead consultations and discussions with trading partners on the use of molecular diagnostics for pest exclusion.
- Contributed to the International Plant Protection Convention (IPPC) Technical Panel for Diagnostic Protocols that supports international standard harmonization.
- PPQ participates in the North American Plant Protection Organization (NAPPO), and in FY 2016, PPQ participated in the development and/or review of protocols for 14 pests. Provided data on diagnostics of wood borer pest interceptions to NAPPO that will impact discussions on wood packaging material regulations.

- CPHST conducted a Next Generation Sequencing study to characterize the utility of this technology on 384 individuals from previous fruit fly population genetic-based pathway analyses using highly variable genetic regions. The results will direct future efforts to understand the location of origin of invasive pest species and demonstrate the potential of this technique to dramatically reduce cost and time of such analyses.
- Over 6,000 gypsy moths intercepted at ports of entry and domestic locations were genetically analyzed for presence of the Asian strain. No Asian gypsy moths were found in the U.S., and only one egg mass was found at a port.
- Further progress was made on completing content development for the “Online identification tools for *Phytophthora*.” The tool was beta tested by 23 researchers in a hands-on workshop conducted at the 2016 American Phytopathological Society meeting. This database will increase the accuracy of *Phytophthora* diagnostics.
- Developed or updated ca. 22 plant pathogen diagnostic methods and established a PPQ cross-functional team to evaluate the use of next generation sequencing (NGS) related to platform selection, cost-benefit and regulatory implications. A roadmap for its use is being developed. Initiated the development of an innovative “Molecular toolbox for Fungi of concern.” This is a high-quality database of sequence files of well authenticated specimens of the CPHST Beltsville Lab collection.
- Initiated “Taxonomists for the Future,” a program to promote the development of U.S. taxonomic

expertise that PPQ can engage for identification needs.

- Developed a Bee Mite ID tool. An Identification tool for bee-associated mite genera of the world that will distinguish mites that harm bees from non-harmful mites. This tool for non-experts will be added to the ITP toolbox.
- Successfully implemented the web-based image library, *imageID*, which aids in pest identification, particularly by PPQ and CBP identifiers. *imageID* is a website that provides enhanced screening efficiency for port and domestic identifiers. *imageID* is now the primary source for visual-based screening of intercepted pests at our ports. During 2016, over 16,000 images were added to the database. By September 2016, *imageID* contained over 87,000 images, representing over 15,700 taxa.

**Better identify and target offshore pest threats:**

- Continued development of an enhanced prioritization tool for the Cooperative Agricultural Pest Survey program to improve the risk basis for rankings and therefore better utilize resources in all 50 States. In FY 2016, the predictive impact model was validated for arthropods by assessing 75 arthropods and comparing results to actual impact. Work on phase II, a model for likelihood of introduction continued.
- Completed analysis of options for the light brown apple moth (*Epiphyas postvittana* Walker) program. A report was prepared that identified baseline and alternative program options, presented modeling results estimating potential future spread of LBAM under different options, estimated

positive and negative impacts of each option on stakeholders (Federal and State governments, fruit and vegetable host crop producers, nursery businesses, exporters of host crops), and developed recommendation for future policy response.

- Completed pathway and economic analyses to support for PPQ decisionmakers determining how to respond to spotted lantern fly.
- Analyzed the risk associated with 43 wood borers and bark beetles from Mexico; characterized the risk of 10 taxa (family or genus level) of organisms intercepted on WPM from Mexico.
- Analyzed the data compiled by the Otis Lab on beetle larvae reared from intercepted in wood packing material, beetle species composition, interception dates, wood species, indicated treatment type, etc., were evaluated for useful patterns of information.
- Responded to stakeholder notifications, country consultations and rulemaking activities related to Q-37 (regulations governing importation of plants for planting) Guatemala *Pelargonium*; and Q-56 (regulations governing importation of fruits and vegetables) Mexico Avocado, South Africa Avocado, and China Fragrant Pear.
- Completed 23 risk assessments and 9 pest lists to support the safe import of fruit and vegetable commodities for consumption and of plants for planting. Fourteen risk assessments from previous years were updated to include the most current information.

- Completed 20 export risk assessments including assessments to expand market access for commercially produced apples and French pears to Israel, *Stenocarpella maydis* (popcorn) to Russian Federation, and corn grain for consumption to South Africa.
- Reviewed other countries' phytosanitary requirements for the export of U.S. maize into Australia, U.S. strawberry, raspberry, and blueberry into Morocco, U.S. blueberry to Peru, and U.S. cherry plants to Peru.
- Pest list reviews for California avocado fruit to India and to Thailand; onions to Jordan; cranberries to China; *Cynodon dactylon* stolons, *Zoysia matrella* stolons, and *Paspalum vaginatum* stolons to Vietnam; fresh peach fruit to China; *Medicago sativa* seeds, *Sorghum* spp. seeds, and *Cynodon dactylon* seeds to Vietnam; *Zantedeschia* spp. to Mexico; *Zantedeschia* spp. and *Eucomis* spp. to Guatemala; weed seeds in *Glycine max* to Russian Federation.
- Analyzed new pests and pests of imminent threat under the New Pest Advisory Group (NPAG) and completed 26 full NPAG reports and 20 preassessments.
- Completed 12 reports on pests recommended for deregulation at ports of entry.
- Completed a pathway and economic impact analysis on the likelihood of reintroduction of pink bollworm (*Pectinophora gossypiella*) (PBW) and impact analysis of the eradication program for pink bollworm. The pathway analysis identified and characterized the potential pathways for reintroduction of PBW into the United States after it is eradicated. The impact analysis evaluated the

efficacy of the PBW eradication program in a cost-benefit framework. The results of the analysis are useful for informing policy and funding decisions if PBW is reintroduced into the United States and technical discussions between U.S. stakeholders and high-risk trading partners regarding mitigation and eradication activities to reduce the likelihood of PBW reintroduction.

- Completed an examination of the evidence that seeds of *Poncirus* genus and hybrids may transmit *Candidatus Liberibacter* species, the causal agent of citrus greening as well as a global pest list of *Citrus* spp. pathogens and an examination of evidence for seed transmission. The results of the analysis provide the technical support for regulations associated with the movement of *Citrus* and *Poncirus* seeds.
- Completed several analyses to support exempting certain commodities from the Light Brown Apple Moth (LBAM) quarantine regulations. The results of this work lessened the regulatory burden on producers within the LBAM quarantine areas.
- Completed an evaluation and pathway analysis for *Xanthomonas vasicola* pv. *vasculorum* (*Xvv*) to support decisionmakers determining how to respond to *Xvv*.
- Noxious Weeds;
  - Completed screening and characterization of 38 plant species for potential risk and to determine if the species are potential targets for exclusion under the Federal Noxious Weed regulations or NAPPRA (Not Authorized Pending Pest Risk Analysis).

- Completed 51 datasheets for NAPPRA listing candidates (weeds); 36 were completed through a cooperative agreement with North Carolina State University's Center for Integrated Pest Management and 15 were completed by PERAL analysts.
- Completed 22 original weed risk assessments (WRAs). Thirteen were completed in support of plants for planting import market access requests. Four were completed in support of fruit and vegetable import market access requests. Two, *Oxalis hispidula* and *Philydrum lanuginosum*, were completed in response to new U.S. detections. One, *Saccharum spontaneum*, was completed in response to a BRS request. Two were completed as part of ongoing safeguarding efforts.

**USDA 24: Provide timely scientific and technical support for emergency response and management**

PPQ must develop and maintain a high level of expertise to support preparedness in the areas of science, technical support, and technology transfer for rapid response efforts.

- The National Plant Protection Laboratory Accreditation Program accredits plant pathogen diagnostic labs and certifies diagnosticians within accredited labs to assist PPQ in screening samples in regulatory surveys. In 2016, NPPLAP developed, validated and distributed proficiency test (PT) panels for HLB, *P. ramorum* and PPV, and administrated PT program for high-consequence plant pathogens to support NPPLAP. Forty-three (43) HLB panels were distributed that resulted in the certification of 38 diagnosticians from 13 laboratories. For *P. ramorum*, 51 panels were distributed

that resulted in 41 diagnosticians from 16 labs being certified. For PPV, 23 participants received panels and 20 diagnosticians from 10 labs were certified.

- CPHST confirmed the presence of plant pathogens first in the United States (*Candidatus, Phytoplasma pini* and *Phytoplasma fraxini*-related, *Xanthomonas vasicola* pv *vasculorum*,
- Mobilized staff to support PPQ's emergency response to a new bacterial disease of corn in the United States. Conducted diagnostic testing and provided diagnostic expertise to additional testing labs. Developed forecasting models, trade, economic, risk and pathway analyses to determine alternative regulatory options, non-regulatory alternatives, areas of spread and impact.
- Supported PPQ emergency response to citrus canker detections in Texas, conducted NGS to determine that the strain primarily affected limes and conducting epidemiological studies to inform PPQ actions.
- Established an unmanned aircraft system (UAS) technical working group to coordinate pilot tests and operational implementation of UAS and develop strategic partnerships on this technology. Assemble a report on the requirements for certification of authorization, economic analysis, strategic sourcing, and information management in a full UAS program. The team is developing a roadmap for PPQ applications and investments in UAS technology for various regulatory programs. Completed successful pilot tests to demonstrate UAS applications, including release of sterile pink bollworm in eradication programs and survey for forest pests such as the Asian longhorned beetle.

**Contributed to the long-term goal of eradicating European grapevine moth (EGVM) from the United States:**

- The EGVM Technical Working Group reviewed the 2015 and 2016 season data with program partners and delivered a report supporting the end of the EGVM quarantine.
- PPQ organized a post-eradication planning group and delivered an eradication plan in January 2016. This was publically posted when EGVM eradication was declared in August.
- A spatial analysis of the eradication program data was conducted that demonstrated the effectiveness of the program's 500 meter quarantine radius for survey and regulation.
- In addition to the target goals, S&T provided quality assurance technical support to ensure the effectiveness of EGVM trapping.
- As a result of the eradication program, and with technical support from PPQ S&T, APHIS successfully completed one of the agency's top 10 goals and declared eradication of EGVM in North America on August 18, 2016.

**CPHST contributed to the long-term goal of preventing citrus greening disease (*Huanglongbing*, HLB) from California:**

- Provided methods support to California program partners that increased their efficiency of *Tamarixia* (the parasitic wasp bio-control agent) production by 31 percent and decreased mortality of collected wasps to lower than 5 percent. The program produced >2.7 million *Tamarixia* and

300,000 *Diaphorencyrtus* in 2016. A new rearing facility starting production in October of 2016 is expected to increase output by another 1.5 million *Tamarixia* per year.

- Evaluating bio-control sites, *Tamarixia* has been established at 92/100 evaluation sites in southern California and at 14/32 monitoring sites in western Arizona at some sites greater than 15 miles from release location indicating widespread establishment of *Tamarixia* is underway in Arizona. In California, *Diaphorencyrtus* recoveries have been made at 10/15 monitoring sites, and recoveries have been made in all counties where releases have been made.
- Intensive sampling and molecular diagnostic testing for citrus greening disease or Huanglongbing (HLB) in Asian citrus psyllids (ACP) collected in Texas and California provided an opportunity to analyze spatial patterns and to locate infections of HLB earlier than plant sampling alone. Taking advantage of the large amount of diagnostic data and spatial location data associated with the samples, CPHST analyzed the spatial pattern of the Ct-values across the landscape. This type of “hot spot” cluster analysis allows us to derive information from these samples and update the maps with potential HLB hot spots. Using this analysis, CPHST identified a potential “cluster” that resulted in finding the San Gabriel, California area infections.
- CPHST evaluated new molecular methods for early detection and the use of root samples for detection. CPHST managed funds and provided field support for the development of canine HLB detection. In addition, administered funds for near-term solutions using enhanced survey tools, soil amendments, thermo-therapy and disease spread models.
- Accurate HLB diagnostics were assured by the NPPLAP Proficiency Test program ensuring lab

capability of correctly performing the USDA Work Instructions for HLB diagnostic testing for USDA regulatory purposes; 34 participant analysts in 12 labs were certified in 2016 for HLB diagnostics.

- Developed and delivered a revised citrus nursery stock (CNS) protocol as well as two nursery stock facility reviews to improve exclusion and quarantine processes.

**Provide scientific methods to the fruit fly program:**

- DNA analyses of oriental fruit fly captures in California and Florida were identified as new introductions to exclude possibility of resurgent population or single high risk pathway. Analyzed two fruit fly captures in south Texas as *Anastrepha* sp, most likely introduced from Mexico. Analyzed Mediterranean fruit flies from four separate capture/interception events during 2016 using the Medfly Molecular Tool (MMT). Specimens from three of the events were interceptions from U.S. ports of entry. The fourth, representing an international collaborative effort, consisted of fruit flies captured in Aruba that were analyzed as per request by the Aruba Ministry of Agriculture.
- Completed confirmatory diagnosis of European cherry fruit flies, *Rhagoletis cerasi*. The specimens were provided by CFIA; the results support the presence of the fly in Canada. CPHST developed and delivered recommendations/protocols for detection trapping for the European cherry fly, which were used to initiate trapping efforts in New York and Pennsylvania.
- Completed the sequencing of eight mitochondrial DNA genomes belonging to *Anastrepha distincta*, *A. ludens*, *A. serpentina*, *A. fraterculus*, *A. obliqua*, *A. suspensa*, *A. grandis*, and *A. striata*, all of

which are considered species of economic importance. Sampling included the *A. ludens* black pupa strain currently being mass reared and released. The information will be used to improve species ID and pathway analyses tools.

- Completed a methods validation study to examine the performance of a SNP genotyping assay used to distinguish lab reared TSL strains of Medfly from wild flies. This technology is the outcome of a collaborative project with USDA ARS to use Next Generation Sequencing for developing rapid diagnostic assays.
- CPHST conducted a Next Generation Sequencing study to characterize the utility of this technology on 384 individuals from previous fruit fly population genetic-based pathway analyses using highly variable genetic regions. The results will direct future efforts to understand the location of origin of invasive pest species and demonstrate the potential of this technique to dramatically reduce cost and time of such analyses.
- In 2016, CPHST released comprehensive updates of the recorded host plants of *Bactrocera cucurbitae*, *B. dorsalis*, *B. tau* complex and *Anastrepha ludens*. These lists are used to generate Federal Orders for regulatory purposes in the implementation of area-wide emergency programs.
- Provided critical technical support to the Dominican Republic to address a major Mediterranean fruit fly outbreak that disrupted trade and was a potential threat to the United States.
- Fruit fly rearing: Developed several improvements in fruit fly rearing for sterile insect eradication programs that will improve quality and reduce costs:

- Replaced torula yeast with toasted soy in larval rearing diet for Mediterranean fruit fly in Guatemala facility, resulting in cost savings of \$185,000/year.
- Developed liquid diet to replace agar diet to feed adults; resulting in annual savings of \$150,000.
- Transferred new black pupal sexing strain of Mexican fruit fly to Texas Mexfly program, resulting in 15 percent reduction in diet costs and significant reduction in equipment and space requirements.

**USDA 25: Improve communications between CPHST and its customers to assure market relevance**

CPHST aims to establish and maintain an effective dialogue with its customers to ensure development activities are useful and applicable to customer needs.

- Through the National Clean Plant Network, S&T built and supports a PPQ-focused network of 29 crop-specific clean plant programs located in 23 centers in 17 States. The NCPN covers 7 crops (fruit trees, grapes, hops, berries, citrus, sweet potato and roses) engaging the work of 100 scientists. In 2016, the NCPN advanced the use and understanding of advanced technology such as next generation sequencing. Critical resources were provided to California, Florida, and Texas in support of the citrus clean plant program quarantine facility and equipment needs of each State to ensure the availability of clean plants for replanting groves affected by citrus greening.
- In order to meet customer needs, conducted a portfolio review of S&T geospatial and predictive modeling activities and developed a roadmap to provide a unified structure, goals, and roles and

responsibilities for geospatial and modeling support.

- Updated export analysis templates and guidelines for training of additional staff in order to expand capacity for export market support. In FY 16, S&T completed 38 analyses to support or maintain access to agricultural export markets.
- Published a biweekly S&T newsletter to enhance communications, with specific sections designated to answer anonymously submitted employee questions, provide EEO and diversity information, and a new section on safety and health issues.
- In addition to annual program review meetings, S&T's citrus health program initiated a listening session with major PPQ and industry stakeholders to better understand the issues that were impacting each citrus State. This session provided new perspectives that influenced new project direction.
- PPQ participates in Commodity Sector meetings each year bringing representative from major commodities sectors such as citrus, potato, cotton, grain, apple, nursery, grapes, etc., that advise and provide constructive comments as to how PPQ and the sectors work together.

**USDA 26: Improve the CPHST work plan development and project prioritization process to assure high quality outcomes for customers / stakeholders**

CPHST will continue to develop a process with PPQ operations to produce mutually acceptable work plans that ensure appropriate product quality.

- Delivered employee training and guidance to all project leaders managing cooperative agreements to ensure high-quality work plans and knowledge of administrative requirements.
- Provided quality management training and guidance to PPQ staff and State cooperators.
- In FY 2016 S&T leadership continued discussions with CPHST labs and held town hall video conference calls with S&T staff.
- Continued development of an enhanced prioritization tool for the Cooperative Agricultural Pest Survey program to improve the risk basis for rankings and therefore better utilize resources in all 50 States. In FY 2016, the predictive impact model was validated for arthropods by assessing 75 arthropods and comparing results to actual impact. Work on phase II, a model for likelihood of introduction continued.
- Provided oversight of 295 cooperative agreements with domestic and foreign researchers and organizations with a total value of over \$32,948,052. S&T receives Farm Bill Section 10007 funding totaling \$12,818,910 for agreement development, and in 2016, the distribution of those funds for cooperative agreements were: 64 percent academia, 5.7 percent international institutions, 3.1 percent industry, 0.6 percent non-profit entities, 10.4 percent State government, and 13.7 percent interagency agreements (ARS and FS). S&T provides administration and management of all Huanglongbing Multi-Agency Coordination Group funding.

**USDA 27: New metrics (beginning FY 2014) on NIFA outcomes**

Efforts to develop procedures for requesting information from NIFA awardees are in progress.

Information will be collected on: (1) number of new jobs created by a small business as the result of receiving SBIR grant funds; (2) increase in sales of technology or services developed by a small business as the result of receiving SBIR grant funds; and (3) sale to other businesses of licenses to technology developed by a small business as the result of receiving SBIR grant funds.

The data on the patents issued based upon Competitive NIFA Funding have been collected for FY 2015 and are now being reported (see Table 1).

**Table 1.** Patents Issued in FY 2016 based upon Competitive NIFA Funding.

<b>Institution Name</b>	<b>Award Number</b>	<b>Patent Number</b>	<b>Issue Date</b>	<b>Invention Description</b>
Colorado State University	2912-34141-20309	5253 (PVP Certified)	5/16/2016	AAC Spendor Russet
Colorado State University	2012-34141-20309	5254 (PVP Certified)	5/16/2016	AAC Stout
University of Wisconsin, Madison	2006-35504-17436	9,150,869	10/6/2015	Sugar Transport Sequences, yeast Strains having Improved Sugar Uptake
University of Wisconsin, Madison	11-CRHF-0-6055	9,180,168	11/10/2015	Use of Glycomacropptide to Improve Women's Health
University of Wisconsin, Madison	2001-335204-10184	9,180,181	11/10/2015	H3 Influenza A Virus
University of Wisconsin, Madison	11CRHF-0-6055	9,187,790	11/17/2015	Sacchiarification of Lignocellulosic Biomass
Michigan State University	20008-51110-04352	9,193,514	11/24/2015	Product Packaging System with Antimicrobial Agent
Auburn University	2009-34605-19805	9,201,048	12/1/2015	Systems for Characterizing Resonance Behavior of Magnetostrictive Resonators
Mississippi State University	Capacity Funding	9,222,032	12/29/2015	Composition and Methods for Improved Fuel Production
Cornell University	2005-35100-16044	9,238,680	1/19/2016	Engineering Heat-Stable Disease Resistance in Plants

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University of Wisconsin, Madison	2005-35503-16303	9,254,266	2/9/2016	Inhibiting Surfaced Enhanced Crystallization of Amorphous Pharmaceuticals
Cornell University	2005-35603-15298	9,267,220	2/23/2016	Nanofibers, Nanotubes and Nanofiber Mats Comprising Crystallizing Metal Oxides
University of Wisconsin, Madison	11-CRHF-0-6055	9,282,738	3/15/2016	Antimicrobial Compositions and Methods of Use Thereof
Pennsylvania State University	Capacity Funding	9,289,435	3/22/2016	Anti-Leukemic Property of Cyclopentenone Prostaglandin Metabolite of Omega-3 Fatty
University of Maryland, College Park	2006-34467-17102	9,321,806	4/26/2016	Novel methods for Recovery of Leaf Proteins
University of Wisconsin-Madison	09-CRHF-0-6055	9,322,068	4/26/2016	Methods and Compositions for Improved Fertilization and Embryonic
Michigan State University	2005-35504-16195	9,328,335	5/3/2016	A Methods to Produce Acetyldiacylglycerols (Ac-Tags)
Auburn University	2010-34605-20651	9,335,292	5/10/2016	Electrochemical Proximity Assay
Michigan State University	2004-34158-15188	9,371,539	6/21/2016	DNA Encoding Ring Zinc-Finger Protein and the Use of the DNA in Vectors
University of Wisconsin-Madison	05-CRHF-0-6055	9,371,562	6/21/2016	Methods and Compositions for Genetically Detecting Improved Milk Production
Mississippi State University	2004-35204-14211	9,375,467	6/28/2016	Live Attenuated Catfish Vaccine and Method of Making
Cornell University	Capacity Funding	9,376,668	6/28/2016	Fagopyritol Synthase Genes and Uses Thereof
University of Wisconsin-Madison	05-CRHF-0-6055	9,422,608	8/23/2016	Methods and Compositions for Improved Cattle Longevity and Milk Production
University of Wisconsin-Madison	09-CRHF-0-6055	9,428,770	8/30/2016	Over-Production of Secondary Metabolites by Over Expression
University of Wisconsin-Madison	04-CRHF-0-6055	9,446,110	9/20/2016	Vaccine Candidates Against Johne's Disease
University of Minnesota	Capacity Funding	PP26600	4/12/2016	Rhododendron Plant Named "UMNAZ 493"
University of Minnesota	Capacity Funding	PP26601	4/12/2016	Rhododendron Plant Named "UMNAZ 502"

**USDA 28: Partner with ARS and the Animal and Plant Health Inspection Service (APHIS) at USDA on the National Plant Diagnostic Network, and the National Animal Health Laboratory Network**

There are two goals for NIFA in this area.

- 1) Develop competitive funding opportunities to include ARS scientists in the development of diagnostic assays and validation protocols that are needed to support APHIS regulatory surveillance efforts for foreign and emerging plant and animal diseases. Plans for FY 2017 are under development
- 2) Coordinate APHIS regulatory and ARS research efforts with relevant components of the Cooperative Extension Service in order to better identify producer needs and the transfer of relevant technology. Plans for FY 2017 are under development.

**USDA 29: ERS is making wider use of social media and new technologies (such as mobile readiness) to widen and expand the reach of our information services to the general public.**

ERS's wider use of social media and new technologies (such as mobile-responsiveness and open data methodologies) widen and expand the reach of our information services to the general public. ERS has been a leading innovator in support of the Administration's Digital Strategy and Open Data initiatives, providing a wealth of products—including data and information—designed to enhance mission delivery.

In FY 2016, ERS used several new tools designed to help consumers more easily access critical programs and stimulate further innovation:

- **Responsive Design:** ERS optimized its website for mobile users, with mobile-friendly pages that automatically adapt to the user's PC, tablet, and smartphone—without having to pinch or expand. This method also provides internal efficiencies in design/production (versus developing multiple style sheets for individual devices/platforms).
- **APIs (Application Programming Interface) for select data and geospatial/mapping applications,** enabling researchers and developers to build applications using ERS data and process for additional insights.
- **Data Visualization:** New tools and technologies have been adopted to present data in a series of active online charts that allow users to interact with ERS data and design charts that reflect different views of data for an enhanced user experience.

The new products and tools extend and expand access to ERS research findings, market outlook, and data—making the agency's information more readily available to the general public. These items were a first among USDA (and many government agencies), enabling USDA to meet its Digital Government Strategy goals to ensure high-value services and systems are available anywhere, any time, and on any device. The work also supports the President's Management Agenda to improve efficiency, share data with entrepreneurs and businesses, and stimulate job growth.

**USDA 30: ERS is exploring new methods for evaluating economic impacts of research collaboration and partnerships between public agricultural research institutions and the private sector.**

In 2012, ERS began a multi-year project to develop metrics to quantify the impact of economic and related social science research and analysis, including measurements of impact of ERS research as evidenced by briefings for senior policy officials, citations of ERS research in the scientific literature, use in government decisionmaking, media citations, and customer use of information published on the ERS website. This initiative is now completed, and the new metrics are now a standard component of the ERS report.

**USDA 31: Engage in consultation with the Agricultural Research Partnerships Network to assist in establishing U.S. commercial partners with foreign entities.**

FAS continued coordination with the ARS/Office of Technology Transfer to engage ARP Network members that were interested in establishing commercial partnerships with foreign entities. FAS developed relevant guidance and talking points that the ARS/Office of Technology Transfer routinely disseminated to ARP Network members that were interested in consulting with FAS. This initiative is completed.

## **1.0. Agricultural Marketing Service (AMS)**

<http://www.ams.usda.gov/AMSV1.0/>

### **1.1. Mission Statement**

The mission of AMS is to facilitate the strategic marketing of agricultural products in domestic and international markets, while ensuring fair-trading practices, and promoting a competitive and efficient marketplace to the benefit of consumers of U.S. food and fiber products. This includes distributing market information, developing grade standards—many of which are used in the voluntary grading programs funded by user fees—protecting producers from unfair marketing practices, testing of commodities for pesticide residues, granting intellectual property rights protection to new plant varieties, and oversight of industry-funded programs to promote agricultural products and research.

### **1.2. Nature and Structure of Program**

The Agricultural Marketing Service (AMS) is a service-oriented organization that provides a vast array of marketing services to the agricultural industry. Its mission is derived from 50 statutes aimed at facilitating the marketing of food and fiber commodities in domestic and international commerce, commodity grade standards, and voluntary certification and inspection programs and laboratory testing. The challenge for AMS is to adapt these programs to changing marketing practices, scientific and technological advances and be responsive to the grading, quality, and health issues facing domestic agriculture. AMS does not have a research and development program in place to address these needs. However, AMS works with other Federal, State, and local agencies, academia and food and fiber industry stakeholders in developing and testing innovative technologies that improve upon current

marketing tools and services in a cost-effective way. Both AMS commodity and support programs and our stakeholders have benefited from this association.

### **1.3. Current Technology Transfer Goals, Objectives, and Measures of Success (Metrics)**

Although AMS does not have a formal technology transfer program in place, the agency does oversee a number of programs where innovative tools and practices have been used to assist agency stakeholders in marketing their food and fiber commodities. This collaboration provides our agricultural stakeholders with a valuable mechanism to introduce new commercial applications and standards to the marketplace, document market-enhancing claims, and uses our various Internet-based e-business portals to facilitate domestic and international trade. Our goal is to provide an entrepreneurial spirit, leverage these program assets to contribute to innovation, job creation, and business opportunities in the agricultural community.

AMS programs that promote these goals include the following:

#### **Plant Variety Protection**

The Plant Variety Protection (PVP) Act (of 1970, and amended in 1994), which provides legal protection in the form of intellectual property rights to developers of new varieties of plants. The intent of the Act is to “encourage the development of novel varieties of sexually reproduced plants and tuber propagated plants and to make them available to the public, providing protection to those who discover, develop, and/or breed new varieties, and thereby promoting progress in agriculture in the public interest.” In order to gain protection over their intellectual property, plant breeders must demonstrate

that their new varieties are distinct from previously existing variety, uniform within each generation of reproduction, and stable across generations of reproduction. Once these standards have been met, plant breeders gain control over the marketing of their new variety (i.e., advertising, exportation, importation, and sales). The term of protection is 20 years for most crops and 25 years for trees, shrubs, and vines. This creates an incentive for investment in the development for new plant varieties. Thus, the PVP Act facilitates technology transfer by protecting the intellectual property rights of those individuals who discover, develop, and/or breed new plant varieties.

The AMS' Plant Variety Protection (PVP) Office has the responsibility for administering the program and is user-fee funded. Since 1970, PVP Office has issued more than 11,200 certificates of protection. The Office maintains crop databases for over 180 species including 70,000 commercial seed-reproduced varieties.

The PVP Office interacts with several Federal agencies and international organizations. These relationships help to coordinate the application of Federal regulations related to the marketing of plant varieties. For example, applicants for PVP certificates are required to submit seed samples or tissue cultures to support and enable their applications. These samples are stored at the National Center for Germplasm Resources Preservation (NCGRP) in Ft. Collins, Colorado. The PVP Office regularly discusses issues of common concern with NCGRP staff. A Memorandum of Understanding, between the two programs, is updated on a regular basis. The seed samples deposited in support of applications are made available to the public after the term of protection ends.

Seeds from outside the United States must be accompanied by a phytosanitary certificate. When they are shipped into the United States, they must be shipped to USDA's Animal and Plant Health Inspection

Service, Plant Protection and Quarantine (PPQ) Office. Once the seeds or tissues pass quarantine, PPQ sends them directly to NCGRP. Plant varieties also need to have a variety name that is unique for marketing purposes. The Federal Seed Act, administered by the AMS' Livestock, Poultry and Seed (LPS) Program, Seed Regulatory and Testing Division oversees truth-in-labeling laws to protect consumers. Such laws cover variety naming and trueness-to-variety testing. The PVP Office uses the services of the LPS Program to determine if the variety names provided in PVP applications are acceptable.

The United States is a member of The International Union for the Protection of New Varieties of Plants, known by its French acronym UPOV. The UPOV treaty sets forth the principles of how intellectual property rights are granted to plants. These principles are then used to enact legislation in each member country, such as the PVP Act and the Plant Patent Act. Regular meetings with UPOV working groups and the governing council helps to update treaty language and processes. As a member of this treaty organization, the PVP Office provides information about what plant varieties are seeking PVP protection. Recently, UPOV released an online version of this information so it is more quickly available to member countries. UPOV is also leading the discussion about harmonization of forms, processes, and the sharing of varietal descriptive information. The PVP Office is actively involved in these discussions.

In fiscal year (FY) 2015 and 2016, the PVP Office received a total of 413 applications, ranging from agronomic crops to flowers and vegetables, requesting PVP. The Office conducted searches on 463 applications to determine whether the plant constituted a new variety. On the basis of those searches, the program issued 467 certificates of protection. At the end of the fiscal year, 7,410 certificates were in force while protection expired for 210 different varieties. During the same period, the Seed Regulatory

and Testing Division cleared 1,312 different variety names and tested 231 trueness-to-variety samples for 3 different kinds of seeds.

The Plant Variety Protection Office (PVPO) is continuing its work to further develop the electronic Plant Variety Protection (ePVP) system by adding additional crops that will bring the total to 55 crops available from the system. The project continues to use the Agile software development technique and has released two versions of the software, release 1 and release 2, internally for examination of 47 crops by the PVPO. The release 3 project will be take place in FY 2017 with a projected release date of June 2017. The fully operational system available to the public and stakeholders is scheduled for an official launch in late calendar year 2017. The ePVP system will allow stakeholders the ability to file new plant variety applications electronically and provide PVPO examination staff with tools to conduct full examinations including variety searches.

### **Pesticide Data Program**

The Pesticide Data Program (PDP) is a critical element in meeting the requirements of the 1996 Food Quality Protection Act (FQPA), which directs the Secretary of Agriculture to provide improved data collection of pesticide residues, standardized analytical and data reporting methods, and increased sampling of foods most likely to be consumed by infants and children. In a collaborative effort, AMS, the Environmental Protection Agency (EPA), and the Food and Drug Administration (FDA) coordinate and prioritize residue-testing and program activities. In addition, AMS conducts annual planning meetings with all program participants, including the cooperating State agencies, other USDA agencies and agricultural industry stakeholders, to select commodities and sampling sites for inclusion in the program.

The data collected reflects the actual residue exposure from food and enables multiple stakeholders to carry out their missions. The EPA uses the data to assess dietary risks from pesticide exposure and determine which pesticides can continue to be used in domestic agricultural production. It also uses the data to harmonize U.S. pesticide tolerance levels with international levels. The FDA uses the data to enhance its surveillance of imported foods. State public health and environmental agencies use the data to fulfill their consumer protection commitments. Growers and distributors use the data to resolve trade issues. This helps to keep diverse crop protection tools available to farmers and producers who benefit, along with consumers, from the continued competitiveness of U.S. agricultural products in the global market. Additionally, the Codex Alimentarius Committee on Pesticides Residues recognizes PDP methodologies as official and validated methods for the determination of pesticide residues in foods.

The AMS' Monitoring Programs Division (MPD) has the responsibility for administering the program, which is an appropriated program. Since 1991, PDP has tested 113 different commodities for over 640 different pesticide residues. In FY 2015, PDP tested over 10,000 samples and generated over 2.3 million data points, including positive residue detections and non-detects. All data are electronically transferred to data users by way of the PDP website or on DVD when requested.

In 2015, sampling services were provided by 10 States (California, Colorado, Florida, Maryland, Michigan, New York, North Carolina, Ohio, Texas, and Washington). Laboratory services were provided by the States of California, Florida, Michigan, New York, Ohio, Texas, and Washington, along with the AMS' National Science Laboratories.

PDP sampled and tested 22 commodities [apples, blueberries, broccoli, carrots, celery, cherries, cucumbers, grapes, green beans (fresh, canned, and frozen), nectarines, oranges, peaches, peanut butter, pears, potatoes, spinach, strawberries, sweet corn, tomatoes, and watermelon] identified by EPA for testing. The program publishes an Annual Summary, which reviews the data collected by each commodity, provides a program overview, and explains sampling and testing methodologies.

AMS released the 2013 PDP Annual Summary in December 2014. The 2013 database contains over 2 million data points. The program plans to release the 2014 Summary by the end of calendar year 2015.

### **Market News and Portal**

The Market News Service (Market News) provides current, unbiased information on supply, demand, prices, movement, location, quality, condition, and other market data on agricultural products in specific markets and marketing areas – both domestic and international. The data is collected for cotton, dairy, livestock, meat, grain, poultry, eggs and specialty crops, including fruits, vegetables, nuts, ornamentals. This information is supplied to buyers and sellers, producers and handlers, transportation and logistics companies, insurance and lending institutions, and others in the marketing chain, including consumers. The information reported by Market News provides a high level of market transparency that contributes to the orderly marketing of agricultural commodities and helps to promote fair trade for all market participants. The market information also supports government policymakers and is widely used for value determinations, such as in courts and mediation.

Federal and State reporters obtain market information on a voluntary basis with the exception of the Mandatory Price Reporting for specified livestock, meat, and dairy product information. The information is accessible through the Internet and e-mail subscriptions. The site issues hundreds of reports daily for some 700 products and commodities resulting in millions of e-views by the public on an annual basis. Market News is currently in the process of expanding farmers market, auction, and regional data sources on the portal and AMS website.

For FY 2017, Market News is continuing to redesign its data and technical infrastructure to improve its service to agricultural market stakeholders by increasing information transparency, reporting speed, accuracy, and flexibility. AMS continues to develop a new market analysis and reporting system (MARS) that will assist in the collection and distribution of commodity information from remote locations.

### **The Livestock Mandatory Reporting Program**

The Livestock Mandatory Reporting (LMR), initiated on April 2, 2001, and reauthorized by the Agricultural Reauthorizations Act of 2015 (P.L. 114-54, Title I), requires market information (i.e., pricing, contracting, and supply and demand conditions) to be reported to AMS by livestock processing plants that annually slaughter a minimum of 125,000 cattle, 100,000 swine, 200,000 sows and boars, or process an average of 35,000 lambs, and by importers who annually import an average of at least 1,000 metric tons of lamb meat products.

The LMR system allows the plants to transfer information electronically in order to meet this requirement. The data that is reported covers 78 percent of slaughtered cattle, 90 percent of boxed beef, 97 percent of slaughtered hogs, 59 percent of slaughtered sheep, 50 percent of boxed lamb meat, and 71 percent of wholesale pork.

Using this marketplace information, AMS implemented a web-based interactive dashboard that provides stakeholders with real time price data paid by packers to producers for cattle, hogs, and sheep; daily and weekly prices received by packers for their sales of boxed beef and boxed lamb to retailers, wholesalers, and further processors; and information on prices received by importers of boxed lamb. It also allows the user the ability to access DataMart in order to gain a historical and/or marketing trend perspective. The livestock and meat industry use the information for production decisions and contract pricing references and formulas. Producers use the data to evaluate market conditions and pricing.

### **Dairy Product Mandatory Reporting**

Public Law 106-532, passed in 2000, required persons engaged in the manufacture and sale of selected dairy products to report certain information including the price, quantity, and moisture content where applicable. Any manufacturer that processes and markets less than 1 million pounds of dairy products per year is exempt from the sales reporting requirements. The Mandatory Price Reporting Act of 2010, passed on September 27, 2010, required USDA to release dairy product sales information reported under Public Law 106-532 and required the establishment of an electronic mandatory sales reporting system.

Mandatory dairy product reporting provides sales information covering 11 percent of butter production,

36 percent of cheddar cheese production, 62 percent of nonfat dry milk production, and 44 percent of dry whey production. AMS collects this data to be used as the price discovery mechanism to establish minimum prices for the Federal milk order system, accounting for 60 percent of the U.S. milk supply. The information in these reports is also used by the dairy industry, impacting current and future production levels.

### **Web-based Supply Chain Management System**

The Web-based Supply Chain Management (WBSCM) is an Internet-based commodity acquisition, distribution, and tracking system that support domestic and international food and nutrition programs administered by four USDA Agencies (Food and Nutrition Service (FNS), Farm Service Agency (FSA), Agricultural Marketing Service (AMS), and Foreign Agricultural Service (FAS)) and United States Agency for International Development (USAID).

AMS manages the WBSCM system, develops products and purchase program technical requirements, and conducts the procurements (solicitations, awards, and contract management) in accordance with Federal regulations and USDA policy. AMS purchases meat, poultry, eggs and egg products, and fruits, vegetables and tree nuts to help stabilize market conditions. The commodities acquired are furnished to FNS to meet the needs of the National School Lunch Program and other domestic nutrition assistance programs. Food purchases are coordinated with FNS to assure that the quantity, quality, and variety of commodities purchased meet the desires of schools and institutions participating in domestic nutrition assistance programs and can be used to assist individuals in meeting the Dietary Guidelines for Americans. The FSA administers the payments to vendors to whom contracts have been awarded, and ensures the proper storage of commodities when necessary. The WBSCM system allows stakeholders to

review and place bids for commodities, receive procurement price information and volume needed, and track the delivery of the purchased commodities. The system transfers information that allows customers and vendors the ability to make informed decisions and improves transparency. The system provides data on more than 200 commodities or 32 billion pounds of food purchased for the domestic and foreign feeding programs administered by AMS, FSA, and FNS, and the USAID. Procurements in WBSCM are valued over \$12 billion. Currently, the system is supporting over 10,000 registered stakeholders, executing more than 7,000 transactions weekly that are involved in the Federal food procurement process and include State and local agencies, school districts, international recipients, commodity suppliers and processors, transportation providers and warehouses.

## 2.0. Animal and Plant Health Inspection Service

### 2.0.1. Introduction

USDA broadly defines technology transfer as the *adoption of research outcomes (i.e., solutions) for public benefit*. Seemingly a simple statement, that process of adoption is complicated, requiring integration of many assets from disparate sources in the successful delivery of solutions. “Public benefit” is achieved through many mechanisms including public release of information, tools, and solutions (e.g., germplasm, plants and other materials), adoption by partners through collaborative research, formal cooperative research and development agreements (CRADA) authorized by the Federal Technology Transfer Act (1986), direct federal, state, or local technical assistance, or through licensing of biological materials or protected intellectual property directly to not-for-profit entities and for-profit private sector firms. This report summarizes the Technology Transfer accomplishments of all APHIS Programs for fiscal year 2015.

### 2.0.2. Combined Metric Tables

**TABLE 1. Collaborative Relationships for Research and Development (R&D)**

APHIS-Wildlife Services (WS)	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
● CRADAs, total active	9	9	9	11	9
- New, executed	3	3	1	1	2
▪ Amendments <sup>1</sup> , total active	2	7	9	8	7
- New, executed	0	5	3	3	2
▪ Traditional CRADAs, total active	9	9	9	11	9
- New, executed	3	3	1	1	2
▪ Small Business Cooperators, total active	5	7	6	8	6
- New, executed	1	2	1	1	2
▪ Foreign Cooperators, total active	6	7	5	3	2
- New, executed	2	1	0	0	0

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• Other Collaborative R&D Relationships					
▪ Confidentiality Agreements <sup>3</sup>	38	48	59	69	74
- New, executed	10	9	9	10	7
▪ Material Transfer Agreements <sup>3</sup>	30	41	71	93	106
- New, executed	9	11	18	34	17
<b>Material Transfer Research Agreements</b>					7
- New, executed					7
▪ Other Agreements <sup>2</sup> , total active	149	81	203	269	320
- New, executed	76	72	107	147	127
• Publications	104	130	147	99	
-Peer-Reviewed (Indexed) Scientific Publications	87	98	142	91	99
-Non-Indexed Publications	17	32	5	8	8
<b>APHIS-Veterinary Services (VS)</b>	<b>FY 2012</b>	<b>FY 2013</b>	<b>FY 2014</b>	<b>FY 2015</b>	<b>FY 2016</b>
• CRADAs, total active	0	0	0	0	0
• Other Collaborative R&D Relationships					
▪ Confidentiality Agreements	0	134	1	0	0
- New, executed	0	134	1	0	0
▪ Material Transfer Agreements	11	21	9	63	64
- New, executed	11	21	9	22	16
<b>Material Transfer Research Agreements</b>				0	0
- New, executed				0	0
▪ Other Agreements <sup>2</sup> , total active	26	24	58	89	170
- New, executed	7	3	23	86	91
• Publications	63	26	35	29	46
-Peer-Reviewed Scientific Publications	61	24	35	29	40
-Trade Journal Publications	2	2	0	0	6
<b>APHIS-Plant Protection and Quarantine (PPQ)</b>	<b>FY 2012</b>	<b>FY 2013</b>	<b>FY 2014</b>	<b>FY 2015</b>	<b>FY 2016</b>
• CRADAs, total active		0	0	0	0
• Other Collaborative R&D Relationships					
▪ Confidentiality Agreements		0	0	1	0
- New, executed		0	0	1	0
▪ Material Transfer Agreements		0	1	9	18
- New, executed		0	1	8	10
<b>Material Transfer Research Agreements</b>				4	4
- New, executed				4	0
<b>ARS Letter of Intent<sup>3</sup></b>				2	0
▪ Other Agreements <sup>2,4</sup> , total active		198	380	389	295
- New, executed		99	147	132	115
• Publications		31	68	54	52
-Peer-Reviewed Scientific Publications		22	39	30	45
-Trade Journal Publications		9	29	20	7

Footnotes for Table 1

<sup>1</sup> Amendments extend existing CRADAs for additional years to a maximum of 5 years, and/or change Statements of Work, and/or change funding levels.

<sup>2</sup> Includes Trust Fund Agreements, Interagency Agreements, Cooperative Agreements, Cooperative Service (Reimbursable) Agreements, Non-Funded Cooperative Agreements and MOUs.

<sup>3</sup> This type of agreement was developed this year to facilitate the rapid exchange of unpublished data from ARS to APHIS PPQ to support regulatory methods and protocols and decision making.

<sup>4</sup> This includes 251 cooperative agreements (CAs); 87 of total funded with Farm Bill Section 10007 funds and 3 of total CAs funded with USDA HLB Multi-agency Coordination Initiative Funds. This also includes 44 interagency agreements (IAs) and 18 of total IAs funded with Farm bill Section 10007 funds.

**TABLE 2. Invention Disclosures and Patenting**

APHIS-Wildlife Services (WS)	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
• New invention disclosures in FY	0	2	2	4	3
• Patent applications filed in FY, total					
▪ Non-Provisional	1	0	0	0	3
▪ Provisional	0	0	0	3	2
• Patents issued in FY					
▪ Life Sciences	0	0	1	1	2
▪ Chemical	0	0	0	0	0
▪ Mechanical & Measurement	1	1	0	0	0
APHIS-Veterinary Services (VS)	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
• New invention disclosures in FY	0	0	1	0	1
• Patent applications filed in FY, total					
▪ Non-Provisional	0	0	0	1	0
▪ Provisional	0	0	0	0	1
• Patents issued in FY					
▪ Life Sciences	0	0	1	1	0
▪ Chemical	0	0	0	0	0
▪ Mechanical & Measurement	0	0	0	0	0

**TABLE 3. Licensing: Profile of Active<sup>1</sup> Licenses**

APHIS-Wildlife Services (WS)	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
• All licenses, total active in the FY					
▪ Patent licenses, total active in FY	1	1	1	1	3
APHIS-Veterinary Services (VS)	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
• All licenses, total active in the FY					
▪ Patent licenses, total active in FY	1	1	1	1	0

<sup>1</sup>Active means legally in force at any time during the FY, whether or not the license is income bearing. USDA licenses are patent invention and material transfer (invention) licenses. There are no other invention licenses or other IP licenses.

**TABLE 4. Income Bearing Licenses<sup>1</sup>**

APHIS-Wildlife Services (WS)	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
• All royalty bearing licenses <sup>1</sup>					
▪ Patent licenses	1	1	1	0	2
APHIS-Veterinary Services (VS)	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
• All royalty bearing licenses <sup>1,2</sup>					
▪ Patent licenses	1	1	1	0	0

<sup>1</sup>Totals include only those licenses that actually *received* royalty income.

**TABLE 5. License Income**

<b>APHIS-Wildlife Services (WS)</b>	<b>FY 2012</b>	<b>FY 2013</b>	<b>FY 2014</b>	<b>FY 2015</b>	<b>FY 2016</b>
▪ Patent licenses	1	1	1	0	3
<b>• Total Earned Royalty Income (ERI)<sup>1</sup></b>					
<b>▪ Patent licenses, total ERI</b>	\$0	\$0	\$0	\$0	\$17,500
<b>APHIS-Veterinary Services (VS)</b>	<b>FY 2012</b>	<b>FY 2013</b>	<b>FY 2014</b>	<b>FY 2015</b>	<b>FY 2016</b>
▪ Patent licenses	0	0	0	0	0
<b>• Total Earned Royalty Income (ERI)<sup>1</sup></b>					
<b>▪ Patent licenses, total ERI</b>	\$0	\$0	\$0	\$0	\$0

**TABLE 6. Disposition of License Income**

<b>APHIS-Wildlife Services (WS)<sup>1</sup></b>	<b>FY 2012</b>	<b>FY 2013</b>	<b>FY 2014</b>	<b>FY 2015</b>	<b>FY 2016</b>
<b>• Income distributed, total</b>					
- To Inventors	\$0	\$0	\$0	\$0	\$6,625
▪ Patent licenses, total	\$0	\$0	\$0	\$0	\$17,500
- To inventors	\$0	\$0	\$0	\$0	\$6,625
<b>APHIS-Veterinary Services (VS)</b>	<b>FY 2012</b>	<b>FY 2013</b>	<b>FY 2014</b>	<b>FY 2015</b>	<b>FY 2016</b>
<b>• Income distributed, total</b>					
- To Inventors	\$0	\$0	\$0	\$0	\$0
▪ Patent licenses, total	\$0	\$0	\$0	\$0	\$0
- To inventors	\$0	\$0	\$0	\$0	\$0

## **2.1. WILDLIFE SERVICES**

[http://www.aphis.usda.gov/wildlife\\_damage/nwrc/](http://www.aphis.usda.gov/wildlife_damage/nwrc/)

### **2.1.1. Mission Statement**

The mission of USDA APHIS Wildlife Services (WS) is to provide Federal leadership and expertise to resolve wildlife conflicts to allow people and wildlife to coexist. Wildlife is an important public resource greatly valued by the American people. However, wildlife is a dynamic and mobile resource that can damage agricultural and industrial resources, pose risks to human health and safety, and affect other natural resources. The WS program carries out the Federal responsibility for helping to solve problems that occur when human activity and wildlife are in conflict with one another. The WS program strives to develop and use wildlife damage management strategies that are biologically sound, environmentally safe, and socially acceptable.

### **2.1.2. Nature and Structure of Research Program**

WS conducts program delivery through its Regional and State Offices and National Programs, providing high quality wildlife damage management services for its customers that result in the protection of agriculture, wildlife and other natural resources, property, and human health and safety. The National Wildlife Research Center (NWRC) is the research arm of Wildlife Services. WS NWRC is the only Federal Laboratory devoted to resolving problems caused by the interaction of wild animals and society.

WS NWRC is headquartered on the Foothills Research Campus of Colorado State University in Fort Collins, CO. The WS NWRC employs more than 150 scientists, technicians, and support personnel at its

Fort Collins, CO, headquarters and at the 7 field stations located throughout the United States and Monell Chemical Senses Center in Philadelphia, PA. Approximately two-thirds of WS NWRC staff is located in Fort Collins. The remainder of the highly specialized staff is located in the other eight locations throughout the United States, facilitating a unique ability to address regional wildlife damage management issues. Further, WS NWRC routinely conducts international consultations in this specialized area.

Scientists at WS NWRC apply a diverse array of expertise to the development of practical, biologically, environmentally, and socially sound methods to resolve these problems and to maintain the quality of the environment shared with wildlife. Scientific staff specializes in several disciplines, including animal behavior/psychology, chemistry, biology, ecology, zoology, economics, genetics, immunology, pharmacology/toxicology, physiology, wildlife biology, and wildlife disease. In addition, WS NWRC works with other experts who have additional specialties through cooperative ties with universities, not-for-profit research facilities, and other public and private research entities.

WS NWRC develops effective wildlife damage management methods through contributions in the following areas:

- Damage assessment
- Investigation of the biology and behavior of problem animals
- Evaluation of the impact of management practices on wildlife and the environment
- Development and improvement of existing management technologies
- Investigation of potential applications of new management technologies
- Support for registration of chemicals, drugs, and devices used to manage wildlife
- Transfer of scientific and technical information

- Provision of scientific guidelines on wildlife damage for use by regulatory agencies
- Development of cooperative research and training with other organizations
- Responsiveness to needs of user groups and the public

### **2.1.3. WS Technology Transfer Goals, Objectives, and Measures of Success**

Scientists at WS NWRC produce methods, technology, and materials for reducing animal damage. Through the publication of results and the exchange of technical information, WS NWRC provides valuable data and expertise to the public and the scientific community, as well as to APHIS' WS program.

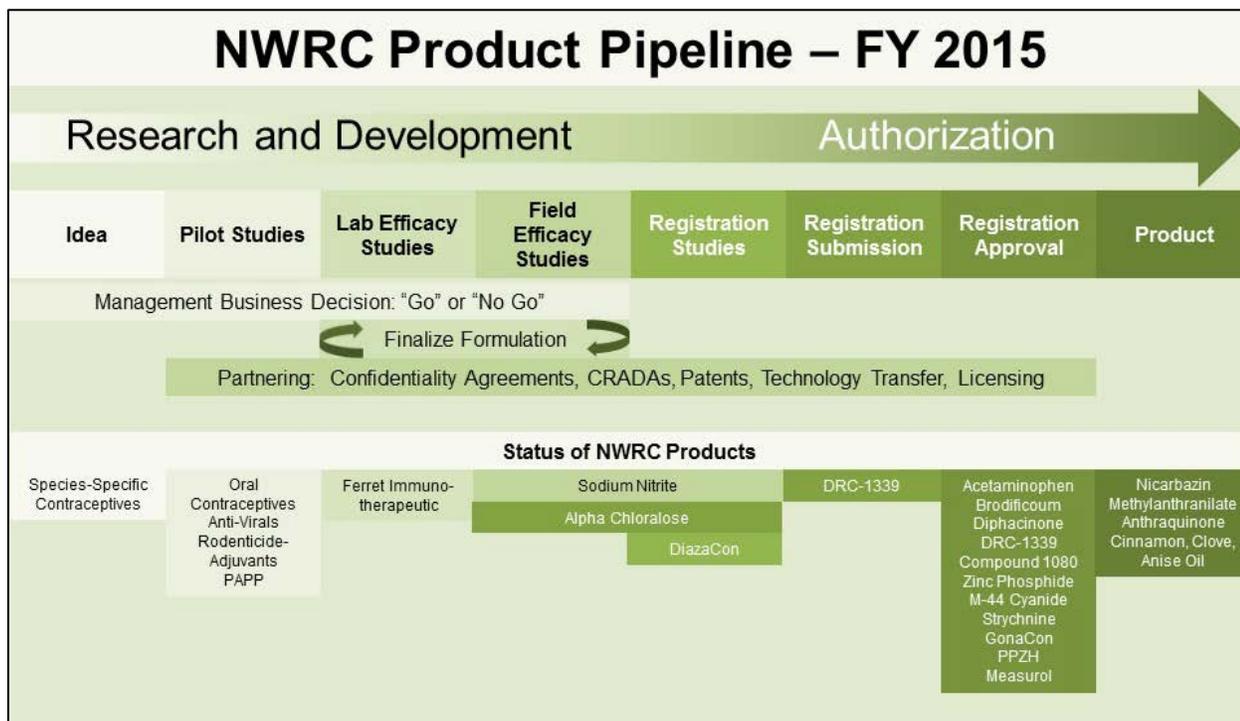
WS follows the general USDA definition of technology transfer as the adoption of research outcomes (i.e., solutions) for public benefit. Through public and private partnerships, WS NWRC research creates new or improved technologies, processes, products, and services that benefit the Nation by increasing productivity, increasing efficiency (keeping costs low), and enhancing global competitiveness for the U.S. agricultural sector. Technology transfer is critical to accelerating use of public research and methods development, creating economic activity, jobs, and sustaining economic development. WS uses formal instruments of technology transfer, including Confidentiality Agreements (CA), Material Transfer Agreements (MTA), Material Transfer Research Agreements (MTRA), and Cooperative Research and Development Agreements (CRADA). In addition, WS transfers technology through patents and invention licenses for commercialization by the private sector. WS has an ongoing formal agreement with ARS Office of Technology Transfer (ARS OTT) to administer WS patents and licensing and to assist with the development CRADAs. WS NWRC's Manager of the Technology Transfer Program serves as the primary liaison for APHIS to the ARS OTT and patent review committee. In

addition, the Manager prepares the APHIS contribution to the USDA Annual Report on Technology Transfer by providing ARS OTT with information on APHIS technology transfer activities and metrics, including tabular metrics of inventions, licenses, CAs, MTAs, MTRAs, CRADAs, as well as other notable “downstream outcomes.”

In addition to patents and licenses, WS transfers knowledge and technology through many other formal and informal mechanisms. Primary among these methods for WS NWRC scientists is publication in peer-reviewed scientific journals. Other important mechanisms for transferring technology and knowledge include presentations at technical or professional conferences and publications in proceedings, technical assistance to the public or stakeholders, informal and formal exchange of information and products among colleagues, public outreach via factsheets, brochures, web pages and social media and laboratory open houses.

WS Operations and the NWRC have dedicated staff devoted to registration/authorization of products with regulatory agencies, including the Environmental Protection Agency’s Office of Pesticide Programs, the Food and Drug Administration’s Center for Veterinary Medicine, and the USDA Center for Veterinary Biologics. When products are developed, they proceed through the research and development pipeline (see schematic below) and are registered with the appropriate regulatory agencies. Products with limited private market potential, but highly desirable to WS Operations, are produced and distributed by the WS Pocatello Supply Depot. Products with significant private market potential are licensed for sale to a private company. Efforts to increase the number of APHIS products licensed by private companies include patenting innovative technology, development of CRADAs and Material Transfer Research Agreements, participating in regional technology development functions, actively participating with the national Federal Laboratory Consortium and the Mid-Continent chapter,

interacting directly with and national, State, and local governments, universities, and industries, and enhancing training for WS NWRC scientists in technology transfer.



WS currently measures success of its technology transfer using several metrics. To measure the success with which WS NWRC scientists are partnering with collaborators, WS NWRC looks at the number of agreements established with collaborators. These include CAs, MTAs, MTRAs, and CRADAs established with partners. However, because many of our partnerships do not necessarily involve the transfer of intellectual property, WS NWRC also follows the number of other agreements established, including cooperative agreements, cooperative service agreements, and interagency agreements, all of which measure the degree of collaboration that WS NWRC has with universities, businesses, other Federal Government agencies, State and local governments, non-governmental organizations, and foreign governments and universities. During FY16, the NWRC had 370 unique institutional collaborations (see the following table).

Institution Type	Number of Unique collaborations
Wildlife Services State Operational Programs	48
Federal	36
State/Local	49
Non-Government Organizations	27
Private Institutions	46
Universities	146
Foreign Governments or Institutions	18
Total	370

Cooperator funding is very important to WS and to WS NWRC in accomplishing their mission. Efforts are being made to increase the amount of cooperator funding generated. For example, cooperator funding at WS NWRC averages about 16 percent of the annual budget. Cooperator funding has steadily increased during the last 5 years, generating \$2.4 million in 2011, and \$2.4 million in 2012, \$2.7 million in 2013 and \$3.5 million in 2014, \$2.6 million in 2015 and \$2.7 million. Agreements with Federal cooperators account for approximately 66 percent of NWRC’s annual incoming cooperator funding, while 34 percent is obtained through agreements with non-Federal collaborators.

WS NWRC tracks its outreach and communication efforts through numbers of technical publications. WS NWRC has a full-time legislative and public affairs staff person and is increasing its outreach efforts through press releases, stakeholder announcements, fact sheets, website postings, social media, facility tours, and workshops. One area we have begun to emphasize is outreach to the business community and communication to WS Operations and stakeholders regarding the economic value received for their research investment. WS NWRC also tracks the number of registrations (existing and new) that have been obtained with regulatory agencies. This is an indicator of new product development that has been provided for use by the public or by WS operational staff.

#### **2.1.4. WS response to Presidential Memorandum on Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Business**

In the USDA's implementation plan for the Presidential Memorandum, WS described three initiatives to promote technology transfer response and commercialization.

##### **USDA 20: Increase awareness in WS of technology transfer mechanisms, leading to increased pace of effective technology transfer and commercialization.**

WS NWRC has traditionally been active in transferring technology and scientific information through use of outreach to collaborators, including WS operational personnel and through publications. Successful outcomes may include improved wildlife damage management practices, scientific information that enhances U.S. competitiveness by protecting crops and property, or increased awareness about wildlife diseases that threaten health of livestock or humans. Most of these outcomes do not require a patent and license for implementation. This initiative is designed to increase awareness among WS personnel about the importance of both formal and informal technology transfer.

The Manager of the Technology Transfer Program provided a formal and information technology transfer training to NWRC biologists at both the headquarters and field locations, increasing the general knowledge and raising the awareness of scientists as to the power of partnerships, importance of developing intellectual property, and the array of technology transfer agreements available to facilitate their research. In addition, WS NWRC's Technology Transfer staff continued to reach out to WS Operations on technology transfer and intellectual property issues. WS Operations staff contacted WS

NWRC's Technology Transfer Program for regulatory advice on issues related to feral swine trapping, four confidentiality agreements.

WS continues to emphasize the importance of collaborative agreements with stakeholders to offset diminishing discretionary funding, while increasing relevance of research to stakeholders, such as the private sector. WS, as part of the annual report table, continues to track the number of agreements it maintains each year, including cooperative agreements, cooperative service agreements, MOUs, and interagency agreements. In addition, WS will track numbers of specific technology transfer agreements, including CAs, MTAs, MTRAs, CRADAs, invention disclosures, and patent and license activity.

During FY 2016, WS NWRC Technology Transfer staff completed 45 unique intellectual property agreements. These included 7 CAs, 18 MTAs, 7 MTRAs, and 2 CRADAs. These agreements brought more than \$683,737 in cooperator funding to the NWRC, allowing scientists to pursue collaborative research aimed at developing products to mitigate wildlife damage issues. In addition, licensing royalties received by NWRC totaled \$17,500, of which \$6,325 were disbursed to inventors, the remainder used internally to support on-going technology transfer efforts. In total, NWRC Technology Transfer efforts accounted for more than \$701,237 in extramural funding.

In addition to traditional technology transfer mechanisms, the WS National Wildlife Research Center publishes scientific manuscripts, book chapters and reports. In FY 2016, the NWRC released 118 publications, including 99 scientific manuscripts in peer-reviewed outlets and 8 in non-indexed outlets. Also during FY16, NWRC scientists served as editors or authors of 10 books or book chapters. NWRC also tracks Internet website traffic and publication downloads. In FY16, the NWRC website saw

143,190 publication downloads from a total of 214 countries. Website referrals were most frequent from Google, Google Scholar, and Google India.

In addition to Center-wide publication efforts, the staff of the Technology Transfer Program published two peer-reviewed manuscripts and submitted two additional manuscripts for publication in non-indexed outlets and one book chapter. The Registration Unit prepared 23 EPA data submissions for registering sodium nitrite as a toxicant for feral swine. These data submissions were part of a CRADA partnership with an Australian enterprise in support of an Experimental Use Permit application to the U.S. Environmental Protection Agency for developing sodium nitrite as a toxicant for feral swine.

**USDA 21: Increase knowledge of WS and NWRC and their impact in preventing wildlife conflicts, leading to increased development of collaborative research and more effective use of public resources.**

WS NWRC has committed to increasing the amount of information disseminated to the general public and stakeholders on research, collaborations, and products provided by the program. The WS NWRC works closely with APHIS public affairs staff in the preparation and dissemination of information on WS NWRC research and collaborations, as well as WS's role as the premier organization for managing human-wildlife conflicts.

As part of continued efforts to increase local and regional community awareness of the WS NWRC, in FY 2016, the Center hosted tours to approximately 240 students, visiting scientists, business and agency partners, and USDA employees. Center representatives hosted booths at several university career fairs to inform students of careers and potential job opportunities with the WS NWRC, as well as funded the

development of a new overview video and 5 shorter video vignettes highlighting the Center's diverse workforce, technology transfer, and unique mission. Through the USDA's blog site, Twitter site, YouTube, and GovDelivery system, WS NWRC notified 10,000+ stakeholders of various research activities, accomplishments, and events. WS NWRC responded to 134 media and community requests for information and published approximately 20 brochures, factsheets, press releases and reports for the general public.

**USDA 22: Increase the pace of WS technology transfer and commercialization activities.**

To accomplish this objective, WS NWRC will increase its efforts to obtain partners for technologies ready to be commercialized by working with ARS and by utilizing the ATIP Program.

WS continues to maintaining existing products and registering new products with the Environmental Protection Agency (EPA) and the Food and Drug Administration for use by WS personnel and the public. In FY 2016, APHIS WS maintained 24 Section 3 registrations with the Environmental Protection Agency and made 1 pesticide Experimental Use Permit (EUP) application submission, and received the EUP EPA exemption for a new active ingredient intended for a product to control feral swine. A total of 20 Section 24c (Special Local Need) pesticide registrations were maintained and 3 new labels were obtained; 1 Experimental Use Permit was in place. In addition, APHIS WS maintained two Investigational New Animal Drug permits with the Food and Drug Administration.

### 2.1.5. Downstream Outcomes

#### eDNA Tools

In controlling invasive species, managers need tools that can help them efficiently direct their activities. The NWRC Wildlife Genetics Project staff has developed new tools to detect invasive species like feral swine. Recent studies have shown that environmental DNA (eDNA) from animals can be detected in bodies of water. eDNA refers to DNA shed by an organism into the environment (e.g., water, soil, or air). The genetic material could come from shed skin, hair, scales, mucous, urine, or feces. In dry areas where water is limited, being able to determine if feral swine are present helps managers decide whether to invest in search and control efforts. The eDNA method can also tell managers when feral swine control efforts have been successful. In addition, it can indicate if residual populations are due to failed eradication efforts or reinvasions. In trials with captive feral swine, researchers learned that eDNA can be detected from a single boar wallowing for 15 minutes in a pool of water and that it degrades after 3.5 days. Researchers also learned that eDNA from multiple wallowing animals takes almost twice as long to degrade. Developing a lab assay that could detect low-quality and -quantity eDNA found in turbid water was challenging. However, NWRC researchers tested many ways to capture and purify eDNA and developed best practices for working with this type of water. Being able to determine if feral swine are present in an area will help managers monitor their distribution nationwide. It will be particularly useful in areas declared free of feral swine, which require surveillance and rapid confirmation of new invasions.



Applying eDNA methods to other invasive species control efforts shows promise, too. The Burmese python is a semiaquatic snake that has invaded Florida, where its elusive nature and cryptic coloration make it difficult to detect. Also, while invasive, the python is not evenly distributed across the Everglades. A detection method that eliminates the need to directly observe or handle snakes and quickly and reliably tells managers whether they are present in an area would make management activities more economical and efficient. To help Florida wildlife managers remove invasive Burmese pythons, NWRC researchers developed a diagnostic polymerase chain reaction (PCR) test that detects python DNA in water. Using captive Burmese pythons, researchers verified the new test and showed that python DNA can be detected in water for up to 96 hours. Researchers also field tested the method by sampling water from six sites in south Florida. Samples from five sites with prior Burmese python sightings tested positive for their DNA. The final site, which had no prior evidence of Burmese pythons, tested negative. This promising new tool is now being used to monitor Burmese python distribution in Florida and inform managers where search and control efforts should take place.

### **Changes to Aircraft Lighting Increase Bird Awareness.**

Collisions between birds and aircraft (also known as bird strikes) are expensive, risk human lives, and increase bird mortality.

Because birds see differently than people, changes to aircraft

lighting have been proposed as a way to make birds avoid aircraft. NWRC researchers and partners from Purdue University investigated brown-headed cowbirds' responses to aircraft lighting systems tuned to match the birds' visual capabilities. Using a remote-controlled aircraft fitted with 470-nanometer lights that exhibit the "blue" portion of the human visual spectrum, scientists observed that cowbirds showed



alert behaviors in less than half the time it took with the lights off. However, for approaching aircraft with pulsing lights, the cowbirds' alert responses were delayed as aircraft speeds increased. This was not the case with approaching aircraft with nonpulsing lights. Also, researchers observed that high ambient noise levels delayed the birds' avoidance of the aircraft, possibly by causing sensory overload and distracting the birds. Researchers believe that placing 470-nanometer lights on aircraft or at airports may improve some birds' abilities to detect and avoid aircraft. The approach may also make wind turbines, towers, and other large stationary structures involved in bird collisions more detectable.

### **Improving Vaccine Technology**

In December of 2015, the U.S. Patent and Trademark Office issued a joint patent “Adjuvanted Rabies Vaccine with Improved Viscosity Profile” (US 9,216,213) to NWRC



researchers and their Merial Ltd. collaborators for a new technology to intensify immune responses in raccoons to rabies vaccines. This technology uses two benign compounds, chitosan and N,N,N trimethylated chitosan (TMC), as adjuvants to make the RABORAL V-RG oral rabies vaccine more viscous, which helps ensure the raccoons have greater oral contact with the vaccine to enhance immune response. The RABORAL V-RG vaccine is delivered as a liquid in a plastic sachet. Under optimal conditions, when an animal's teeth pierce the sachet, the vaccine is released into its mouth and absorbed. While foxes and coyotes tend to pick up the entire bait with their mouths, releasing a full dose of vaccine as they chew, raccoons and skunks sometimes hold the vaccine sachet on the ground and bite only small portions at a time, allowing the open sachet to leak. Chitosan is deacetylated chitin, a nontoxic polymer that naturally occurs in crustaceans, insects, and mushrooms. When chitin is converted to chitosan, it becomes a gelatinous precipitate that enhances the transport and absorption of vaccines or

drugs. In NWRC studies, the addition of TMC to existing RABORAL V-RG bait allowed raccoons to consume baits more easily and without leakage and did not interfere with the vaccine-induced immunity. NWRC is now seeking licensing partners for this new technology.

## **2.2. BIOTECHNOLOGY REGULATORY SERVICES (BRS)**

<http://www.aphis.usda.gov/biotechnology/index.shtml>

### **2.2.1. Mission Statement**

The mission of BRS is to protect and enhance U.S. agricultural and natural resources using a dynamic, science-based regulatory framework to ensure the safe importation, interstate movement, and environmental release of genetically engineered (GE) organisms.

### **2.2.2. Nature and Structure of Program**

BRS does not perform research. BRS regulates the introduction (importation, interstate movement, and release into the environment) of GE organisms that may pose a risk to plant health. Researchers and product developers, Federal or private, should understand and work with the appropriate regulatory agencies that may have oversight of an organism at different stages in the development of a product. This can facilitate efficient development of the appropriate information necessary for regulatory review.

Since 2009, BRS has provided compliance assistance to the regulated community for the voluntary adoption of a Biotechnology Quality Management System (BQMS) Program. A BQMS serves as an important tool to help organizations involved in biotechnology research and development analyze the critical control points within their management system to better maintain compliance with USDA APHIS regulations for the import, interstate movement, and environmental release of regulated GE organisms (7 CFR part 340).

The BQMS Program integrates a dynamic, science-based approach of risk assessment and mitigation, allowing for sound decisionmaking and effective management of the research and development of regulated GE organisms. The program integrates principles from other quality management systems, such as the Codex Alimentarius Hazard Analysis and Critical Control Point System, and ISO 9001:2008. The BQMS Program offers to organizations a flexible approach to implementing a quality management system, where the BQMS is tailored to the organization's individual size and research scope. The BRS Office of Compliance Assistance provides participants with the tools and guidance needed to develop a BQMS through training, documented guidelines, and one-on-one assistance. BRS provides an initial assessment of an organization's regulatory compliance processes and assists with periodic reviews and audits of the organization's BQMS. Twenty organizations, including public-sector research institutions and multi-national corporations, have voluntarily established a BQMS within their organization through the services provided by BRS. These organizations share common goals of responsible research and facilitating regulatory compliance. Information on the APHIS BRS BQMS Program can be found at [http://www.aphis.usda.gov/biotechnology/compliance\\_assistance\\_main.shtml](http://www.aphis.usda.gov/biotechnology/compliance_assistance_main.shtml).

## **2.3. INTERNATIONAL SERVICES**

[http://www.aphis.usda.gov/international\\_safeguarding/index.shtml](http://www.aphis.usda.gov/international_safeguarding/index.shtml)

### **2.3.1. Mission Statement**

The mission of International Services (IS) is to protect U.S. agricultural and natural resources by working with foreign governments to prevent the spread of high-risk plant pests and animal diseases; facilitate the safe international movement of agricultural commodities through science-based regulations and internationally accepted standards; and enhance global health and U.S. biosecurity through the development of science-based regulatory systems and policies around the world.

### **2.3.2. Nature and Structure of Program**

IS' overseas presence enables APHIS to monitor and respond to pest and disease threats, develop international strategies and partnerships to prevent their spread to the United States, and support U.S. agricultural trade by resolving technical barriers. Through its services, IS contributes directly to global food security by promoting safe global trade and facilitating the development of science-based regulatory systems around the world. IS works closely with other APHIS programs, including Veterinary Services (VS), Plant Protection and Quarantine (PPQ), Biotechnology Regulatory Services (BRS), and Wildlife Services (WS) to ensure that its daily work overseas reflects the priorities of these domestic programs. This collaboration is key to IS' success and is achieved through joint planning, enhanced communications, clear direction to the field, and implementing coordinated strategies. IS uses technology transfer to support APHIS' work overseas by creating linkages and supporting partnerships, collaborations, and cooperative programs. As part of its mission to safeguard U.S. agriculture and expand the safe exportation of unprocessed agricultural products, IS works with

international partners through bilateral and multilateral treaties and agreements to improve animal and plant health systems around the world. IS partners with international organizations, including the International Atomic Energy Agency (IAEA), World Organization for Animal Health (OIE), the Food and Agriculture Organization of the United Nations (FAO), and the International Regional Organization for Agricultural Health (OIRSA), as well as with our international trading partners to help implement appropriate technologies to control or eliminate sanitary and phytosanitary (SPS) threats to the safe trade of agricultural products.

IS has organized and led several pest control programs in the Americas designed to reduce or eliminate populations of pests like Screwworm, Mediterranean fruit fly (Medfly), and Mexican fruit fly (Mexfly). The control of these very costly pests requires a specific set of technologies involving several different control measures, including the design and methods of release of sterilized male flies, the application of environmentally friendly pesticides, and the design and application of fly traps for surveillance and population reduction. IS has also developed a robust information management system and database that both the Screwworm and Medfly Commissions use, which facilitates the sharing of critical information among partners. IS works throughout Central America and the Caribbean to transfer technologies for effective and sensitive fruit fly surveillance and control in collaboration with its international partners and the USDA's Agricultural Research Service.

The most recent example of this technology transfer occurred following detections of Medfly in the Dominican Republic in early 2015. The Dominican Republic is a member of the CAFTA-DR (Central America – Dominican Republic) free trade agreement, and these countries constitute the United States' fifth-largest trading partner in agricultural products. IS has transferred to the Dominican Republic many of the technologies necessary to mitigate this critical threat to the United States. IS's Action Program

office in Guatemala City, which focuses on the Medfly program, shares this Geographic Information System (GIS) and Global Positioning System (GPS) technology with federal agencies within Mexico, Guatemala, and Belize as well.

During 2016, IS supported the efforts of OIRSA to test a computer application for mobile telephones to access surveillance data and test results from the Central American Reference Laboratory for Vesicular Diseases (LADIVES) in Panama. Once implemented, this technology will improve information sharing, especially on important diseases such as Foot-and-mouth disease (FMD) and Screwworm. IS has also provided support to OIRSA to create a census database for Central American livestock farmers.

Employees of COPEG (The Screwworm Barrier Maintenance Program), managed by the United States and Panamanian governments in Panama, trained domestic APHIS personnel to support the Screwworm outbreak in Florida. Technical training included the identification of adult and larval Screwworm, sexual dimorphism, terrestrial ground release and live capture techniques, secure shipment of fertile material, and the transport and management of sterile pupae for ground release.

COPEG technical staff also trained four master's degree students from the Universidad de Las Americas, sponsored by the Panamanian Ministry of Health, during a 3-day rotation in COPEG's Radiation Department. The students helped perform irradiation work, were given theoretical problems to solve, and received instruction in radiation safety practices and the use of personal and handheld dosimeters.

Additionally, the monitoring of technology transfer from APHIS to the Haitian Ministry of Agriculture constitutes part of an agreement between USDA and the U.S. Agency for International Development (USAID) focused on improving public plant health services in Haiti. To date, over 10 different

technologies have been transferred to Haiti to improve fruit fly surveillance and control as part of our ongoing effort to safeguard U.S. agriculture and improve safe food production for the world. In FY 2016, APHIS implemented the Exotic Fruit Fly Program in response to the Medfly outbreak in the neighboring Dominican Republic, which included a bilingual English/French Emergency Program work plan. Haiti exports over 16 million mangoes to the United States each year, and since this collaboration began, new mango production areas have been added, which resulted in a 52-percent increase in export revenues.

The U.S. Feral Swine Damage Management Plan includes several activities where WS, VS, and IS play important roles. The goal of the Feral Swine Program in Mexico is to integrate Mexican federal agencies into the North American regional group to develop joint activities for Feral Swine damage management. As part of these efforts, IS in Mexico City worked with the School of Veterinary Medicine and Animal Science of the National Autonomous University of Mexico (UNAM) to develop a series of workshops to share perspectives and ideas. The goal was to demonstrate to attendees procedures for feral swine damage control developed in the United States as part of the National Feral Swine Damage Management Plan as a reference for the Mexican counterparts to help them develop their own control methods.

During FY 2016, IS staff from Mexico organized, coordinated, and developed three feral swine damage management workshops, a Feral Swine symposium, and an international meeting with members of VS and WS and a group of UNAM academics. Scientists from IS and WS described steps the United States is taking for feral swine control, particularly building corral traps to trap the animals for removal or slaughter. Attendees discussed other feral swine control procedures including different types of individual and corral traps, hunting, hunting over bait, hunting at night, hunting with dogs,

trapping/snares, fencing, and advanced control methods such as poisoning and immuno-contraception that were developed in United States. IS plans to hold similar workshops in FY 2017 to train staff from other Mexican states, including Sonora, Baja California, Tamaulipas, and the Central Region of the country. Coordination among WS and IS is essential for the success of these activities, as IS is the primary organization for the U.S.-Mexico binational negotiations to develop activities in the Feral Swine Program.

Our long-standing support of FMD eradication from the Western Hemisphere is another example of technology transfer from the United States to foreign counterparts. USDA has been an active signatory partner in this effort for over 35 years. From the beginning of this international effort involving treaties and agreements between the United States and our trading partners in the Western Hemisphere, the United States has been an effective leader in the transfer of effective FMD surveillance and control strategies. Each of these strategies in turn relies on several different technologies, for which the United States is usually the leader in developing. The United States has signed several treaties and international agreements through the Department of State and via the USDA to support the hemispheric effort through technology transfer.

These technologies have included high-volume vaccine production, infra-red surveillance for febrile illnesses, animal computer-chip ear-tag identification, computerized methods of managing surveillance, and sanitation technologies in slaughter facilities. FMD poses a constant threat to livestock production in the United States, with the potential to devastate our beef and pork industries if the virus were to appear in the United States. Between 1980 and 2010, the FMD virus was successfully reduced from its widespread presence throughout South America to its current presence only in Venezuela, where the situation is critical. The campaign to eradicate FMD from the Western Hemisphere is nearly complete,

and it could not have been accomplished without the active participation of the United States in transferring essential technologies to the program.

### **2.3.3 Downstream Outcomes**

#### **International Technical and Regulatory Capacity Building (ITRCB)**

The ITRCB, a unit of APHIS-IS, acts as a clearinghouse to review requests for APHIS technical assistance. When appropriate, ITRCB supports agency efforts to facilitate technical cooperation activities with trading partners and developing countries. The training of foreign counterparts comprises a significant level of effort of the ITRCB unit. Although technology transfer is somewhat limited, APHIS-IS is an active leader in developing new methods to support the agency's control and eradication efforts of quarantine pests.

Under the APHIS-IICA (Inter-American Institute for Cooperation on Agriculture) cooperative agreement for capacity building initiated in 2014, APHIS revised the 2015 work plan to provide agreement resources to Dominican Republic plant health authorities to help control and eradicate the outbreak of Medfly in the country's eastern region. In 2016, an expert consultant provided on-the-ground technical assistance to assist the Dominican authorities. APHIS developed a technical scope of work, which detailed the required skills, abilities, and experience required to conduct this consultancy. The objective of the consultancy was to work closely with the Dominican authorities currently combating the outbreak, provide technical assistance and guidance to them, and to report progress to IICA and APHIS periodically.

## **2.4 PLANT PROTECTION AND QUARANTINE**

[http://www.aphis.usda.gov/plant\\_health/index.shtml](http://www.aphis.usda.gov/plant_health/index.shtml)

### **2.4.1. Mission Statement**

We safeguard U.S. agriculture and natural resources against the entry, establishment, and spread of economically and environmentally significant pests and we facilitate the safe trade of agricultural products.

### **2.4.2 Nature and Structure of PPQ's Methods and Technology Development Program**

PPQ's technology development is facilitated and implemented through cooperation between its three divisions; namely Policy Management (PM), Field Operations (FO), and Science and Technology (S&T). The Center for Plant Health Science and Technology (CPHST) is the primary component of PPQ's Science and Technology core functional area, which also includes the National Clean Plant Network (NCPN). APHIS is one of three agencies of the USDA (along with ARS and NIFA) that, through a memorandum of understanding, support research, quarantine, and outreach activities for the NCPN. The NCPN is "*a voluntary association of specialty crop networks that promote the use of pathogen-tested, healthy plant material for food crops in the United States*"

(<http://nationalcleanplantnetwork.org/about/>).

CPHST provides scientific and technical support for the regulatory decisions, policies, and operations of APHIS' Plant Protection and Quarantine (PPQ) program in order to safeguard U.S. agriculture and natural resources. CPHST is responsible for ensuring PPQ has the information, tools, and technology to

make the most scientifically valid policy and regulatory decisions possible and is headquartered on the campus of North Carolina State University in Raleigh, North Carolina. The broader CPHST system however consists of approximately 216 scientists, analysts, and support staff at 7 principal laboratories, 2 stations and satellite locations throughout the United States and in Guatemala. It also includes four programs and multiple work units. CPHST supports regulatory plant protection activities by developing methods and conducting analyses in the following program areas: AQI/Commodity Treatment Support, Trade Issues and Risk Analysis, Identification and Diagnostics, Pest Detection, and Pest Management.

In FY 2016 CPHST continued the expansion of operations for construction of a new laboratory in California. The location selected for this laboratory is in Sacramento, CA, adjacent to the California Department of Food and Agriculture's Meadowview facility. The new lab will foster cooperation with one of the premier State regulatory labs, regional universities such as UC Davis, ARS labs, industry, and fills a major need for additional science and technology support for West Coast pest programs and agricultural trade. This effort will continue as a major S&T initiative for FY 2017.

CPHST activities primarily focused on providing scientific support for PPQ needs and decisionmaking, but also supported stakeholders such as State plant regulatory programs and the agricultural and nursery industries. CPHST conducts its work with internal stakeholders but also engages other Federal agencies (e.g. ARS, NIFA, Forest Service, DOE National Labs, DHS and EPA), Tribal Nations, academia, international institutions, and industry to acquire knowledge, best management practices, products and protocols, and to develop methods and protocols needed for plant protection and management of invasive pests.

### 2.4.3 Current Technology Transfer Goals, Objectives, and Measures of Success

PPQ is committed to use of the best science, tools, and technologies to strengthen the efficiency and effectiveness of PPQ's work. PPQ transfers new methods and technology through several mechanisms: technical documents, protocols, risk assessments, and pest survey guidelines that are distributed directly to stakeholders or are made available through PPQ websites. Another important mechanism to transfer information is through the publication of results in peer-reviewed scientific journals. Other important mechanisms for transferring technology and knowledge include hands-on training at our labs, presentations at technical or professional conferences, publications in proceedings, trade publications, and direct technical assistance to the public, stakeholders, and industry through various outreach activities and events.

The CPHST Identification Technology Program (ITP) is an internationally recognized scientific resource and provides digital pest identification tools that are available online (<http://idtools.org>) and used by APHIS scientists as well as scientists in Customs and Border Protection, in State departments of agriculture, in domestic and international academic institutions, and also by national and regional plant protection organizations to identify plant pests. CPHST continues to develop two image-based products ([ITP Node](#) and [imageID](#)) that support the increasing demand for high-quality, taxonomically useful images for expediting plant pest screening. The ITP Node, developed in cooperation with The University of Georgia, was created in response to domestic partners' request for access to CPHST's existing image collections. By the end of 2016, the ITP Node contained 27,273 images – over 4,000 were added in 2016. The Node's site is now responsive, allowing smartphone and tablet users to search and download pest images to their mobile devices. imageID is a website that provides specific

navigation, functionality, content, and interfaces to enhance screening efficiency for port and domestic identifiers. Released in 2014, imageID is now the primary source for visual-based screening of intercepted pests at our ports. During 2016, over 16,000 images were added to the database. By September 2016, imageID contained over 87,000, representing over 15,700 taxa.

CPHST provides technical training to stakeholders in certain areas (i.e. diagnostic testing, pest risk assessment, treatments) and also provides information and training on quality management and accreditation. For example, the CPHST Beltsville Lab provides hands-on training on molecular diagnostics for regulated plant diseases to diagnosticians from State and academic laboratories and in FY 2016 conducted 7 training workshops for 35 diagnosticians. The Mission, Texas Lab organized and shared new molecular identification techniques with 30 fruit fly experts from HI, CA, TX, and FL and developed strategies to leverage resources that will increase the national capacity to diagnose pests. The CPHST Quality Management Program provided auditor training in several sessions with diagnosticians of the NIFA National Plant Diagnostic Network (NPDN) and organized on-site audits of several NPDN labs in an effort to support the NPDN quality management system STAR-D.

The National Plant Protection Laboratory Accreditation Program (NPPLAP) accredits State, Federal, industry and academic laboratories. In FY 16 NPPLAP had 26 active accredited labs. Technicians are certified by NPPLAP to perform specific diagnostics through development and distribution of proficiency tests (PT). In FY 2016, 107 certifications were granted to carry out diagnostic testing of regulated samples. Internationally, three labs in Colombia participated in the PT. The NPPLAP currently manages PT programs for Plum Pox Virus, *Phytophthora ramorum* and Citrus Greening testing. Two new services were offered by the NPPLAP: test results submission online facilitated by

the NAHLN portal and the Planned Deviation process. The NAHLN portal is used for VS diagnostic labs participating in proficiency testing for regulated animal diseases. Development has been completed for the implementation of a NPPLAP PT site maintained by both programs for increased confidentiality, easier results submission for our participants, review processes, and improved information of participating lab capabilities. Planned Deviations are comparability studies designed by NPPLAP for accredited labs seeking to use different instruments or reagents than specified in validated PPQ work instructions. A Planned Deviation ensures comparability between the change and existing processes do not affect the integrity of the results. Five labs at academic institutions or State departments of agriculture participated in six studies that resulted in method improvements and provided flexibility that benefited participating labs. Proficiency test program plans are also designed by NPPLAP to additionally provide post-validation monitoring of PPQ validated tests and the establishment of reference materials for all three provided disease PT programs. Test materials are validated to international standards, conforming to ISO Guide 34 and ISO/IEC 17043:2010. Validated PT materials are rare and in high demand by the international community.

Formal agreements, including cooperative and interagency agreements and memoranda of understanding, are used to formalize collaborations with other government scientists, universities, private companies, and other stakeholders. In FY 2016, CPHST ended the year with 295 active agreements including 115 new agreements. The total includes 251 cooperative agreements, 87 of which are funded with Farm Bill Section 10007 funds and 3 of which are funded with USDA HLB Multi-agency Coordination Initiative funds. The total also includes 44 interagency agreements, 18 of which are funded with Farm Bill funds.

In FY 2016, PPQ continued the interagency agreement with the ARS Office of Technology Transfer

(ARS-OTT) along with VS and WS to execute formal technology transfer activities on our behalf of PPQ. ARS-OTT worked with the PPQ National Scientific Technologies Coordinator to provide technology transfer agreements training to the PPQ Phytosanitary Issues Management (PIM) program. PIM facilitates and negotiates, through the use of scientifically based processes, the safe export and import of agricultural commodities. The training with PIM focused on IP safeguarding while sharing scientific products with our trading partners. PPQ worked closely with the ARS-OTT to identify technology transfer opportunities and will continue to in FY 2017 as CPHST reviews projects for additional technology transfer needs.

#### **2.4.4 APHIS-PPQ Response to Presidential Memorandum on Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Businesses**

In the USDA's implementation plan for the Presidential Memorandum, APHIS-PPQ described four initiatives to promote technology transfer and commercialization. The initiatives and their implementation in FY2016 are described below.

##### **USDA 23: Enhance collaboration efforts in pest detection and management**

PPQ's scientific support focuses on improving and developing pest detection and management tools to discover new invasive species early and respond quickly, better identify and target offshore pest threats, develop diagnostic tools and techniques, and transfer technology to cooperators and impacted industries.

**Strengthen PPQs pest exclusion system:**

- Completed analysis of three molecular diagnostic pilots at four PPQ Plant Inspection Stations to evaluate the use of molecular diagnostics at Plant Inspection Stations. A Molecular Diagnostics Working Group (MDWG) was formed and began developing a framework for implementing molecular diagnostic to support plant inspections at ports of entry. A team is being established to lead consultations and discussions with trading partners on the use of molecular diagnostics for pest exclusion.
- Contributed to the International Plant Protection Convention (IPPC) Technical Panel for Diagnostic Protocols that supports international standard harmonization.
- PPQ participates in the North American Plant Protection Organization (NAPPO) and in FY 2016, participated in the development and/or review of protocols for 14 pests. Provided data on diagnostics of wood borer pest interceptions to NAPPO that will impact discussions on wood packaging material regulations.
- CPHST conducted a Next Generation Sequencing study to characterize the utility of this technology on 384 individuals from previous fruit fly population genetic-based pathway analyses using highly variable genetic regions. The results will direct future efforts to understand the location of origin of invasive pest species and demonstrate the potential of this technique to dramatically reduce cost and time of such analyses.

- Over 6,000 gypsy moths intercepted at ports of entry and domestic locations were genetically analyzed for presence of the Asian strain. No Asian gypsy moths were found in the United States and only one egg mass was found at a port.
- Further progress was made on completing content development for the “Online identification tools for *Phytophthora*.” The tool was beta tested by 23 researchers in a hands-on workshop conducted at the 2016 American Phytopathological Society meeting. This database will increase the accuracy of *Phytophthora* diagnostics.
- Developed or updated ca. 22 plant pathogen diagnostic methods and established a PPQ cross-functional team to evaluate the use of next generation sequencing (NGS) related to platform selection, cost-benefit and regulatory implications. A roadmap for its use is being developed. Initiated the development of an innovative “Molecular toolbox for Fungi of concern.” This is a high-quality database of sequence files of well authenticated specimens of the CPHST Beltsville Lab collection.
- Initiated “Taxonomists for the Future” a program to promote the development of U.S. taxonomic expertise that PPQ can engage for identification needs.
- Developed a Bee Mite ID tool. An Identification tool for bee-associated mite genera of the world that will distinguish mites that harm bees from non-harmful mites. This tool for non-experts will be added to the ITP toolbox.
- Successfully implemented the web-based image library, *imageID*, which aids in pest identification,

particularly by PPQ and CBP identifiers. *imageID* is a website that provides enhanced screening efficiency for port and domestic identifiers. *imageID* is now the primary source for visual-based screening of intercepted pests at our ports. During 2016, over 16,000 images were added to the database. By September 2016, *imageID* contained over 87,000, representing over 15,700 taxa.

**Better identify and target offshore pest threats:**

- Continued development of an enhanced prioritization tool for the Cooperative Agricultural Pest Survey program to improve the risk basis for rankings and therefore better utilize resources in all 50 States. In FY 2016, the predictive impact model was validated for arthropods by assessing 75 arthropods and comparing results to actual impact. Work on phase II, a model for likelihood of introduction continued.
- Completed analysis of options for the light brown apple moth (LBAM) (*Epiphyas postvittana* Walker) program. A report was prepared that identified baseline and alternative program options, presented modeling results estimating potential future spread of LBAM under different options, estimated positive and negative impacts of each option on stakeholders (Federal and State governments, fruit and vegetable host crop producers, nursery businesses, exporters of host crops), and developed recommendation for future policy response.
- Completed pathway and economic analyses to support PPQ decisionmakers determining how to respond to spotted lantern fly.

- Analyzed the risk associated with 43 wood borers and bark beetles from Mexico; characterized the risk of 10 taxa (family or genus level) of organisms intercepted on WPM from Mexico.
- Analyzed the data compiled by the Otis Lab on beetle larvae reared from intercepted in wood packing material, beetle species composition, interception dates, wood species, indicated treatment type, etc., were evaluated for useful patterns of information.
- Responded to stakeholder notifications, country consultations, and rulemaking activities related to Q-37 (regulations governing importation of plants for planting) Guatemala *Pelargonium* and Q-56 (regulations governing importation of fruits and vegetables) Mexico Avocado, South Africa Avocado, and China Fragrant Pear.
- Completed 23 risk assessments and 9 pest lists to support the safe import of fruit and vegetable commodities for consumption and of plants for planting. Fourteen risk assessments from previous years were updated to include the most current information.
- Completed 20 export risk assessments including assessments to expand market access for commercially produced apples and French pears to Israel, *Stenocarpella maydis* (popcorn) to Russian Federation, and corn grain for consumption to South Africa.
- Reviewed other countries' phytosanitary requirements for the export of U.S. maize into Australia, U.S. strawberry, raspberry, and blueberry into Morocco, U.S. blueberry to Peru, and U.S. cherry plants to Peru.

- Pest list reviews for - California avocado fruit to India and to Thailand; onions to Jordan; cranberries to China; *Cynodon dactylon* stolons, *Zoysia matrella* stolons, and *Paspalum vaginatum* stolons to Vietnam; fresh peach fruit to China; *Medicago sativa* seeds, *Sorghum* spp. seeds, and *Cynodon dactylon* seeds to Vietnam; *Zantedeschia* spp. to Mexico; *Zantedeschia* spp. and *Eucomis* spp. to Guatemala; weed seeds in *Glycine max* to Russian Federation.
- Analyzed new pests and pests of imminent threat under the New Pest Advisory Group (NPAG) and completed 26 full NPAG reports and 20 preassessments.
- Completed 12 reports on pests recommended for deregulation at ports of entry.
- Completed a pathway and economic impact analysis on the likelihood of reintroduction of pink bollworm (*Pectinophora gossypiella*) and impact analysis of the eradication program for pink bollworm. The pathway analysis identified and characterized the potential pathways for reintroduction of PBW into the United States after it is eradicated. The impact analysis evaluated the efficacy of the PBW eradication program in a cost-benefit framework. The results of the analysis are useful for informing policy and funding decisions if PBW is reintroduced into the United States and technical discussions between U.S. stakeholders and high-risk trading partners regarding mitigation and eradication activities to reduce the likelihood of PBW reintroduction.
- Completed an examination of the evidence that seeds of *Poncirus* genus and hybrids may transmit *Candidatus Liberibacter* species, the causal agent of citrus greening as well as a global pest list of *Citrus* spp. pathogens and an examination of evidence for seed transmission. The results of the

analysis provide the technical support for regulations associated with the movement of *Citrus* and *Poncirus* seeds.

- Completed several analyses to support exempting certain commodities from the Light Brown Apple Moth (LBAM) quarantine regulations. The results of this work lessened the regulatory burden on producers within the LBAM quarantine areas.
  
- Completed an evaluation and pathway analysis for *Xanthomonas vasicola* pv. *vasculorum* (Xvv) to support decisionmakers determining how to respond to Xvv.
  
- Noxious Weeds;
  - Completed screening and characterization of 38 plant species for potential risk and to determine if the species are potential targets for exclusion under the Federal Noxious Weed regulations or NAPPRA (Not Authorized Pending Pest Risk Analysis).
  - Completed 51 datasheets for NAPPRA listing candidates (weeds); 36 were completed through a cooperative agreement with North Carolina State University's Center for Integrated Pest Management and 15 were completed by PERAL analysts.
  - Completed 22 original weed risk assessments (WRAs). Thirteen were completed in support of plants for planting import market access requests. Four were completed in support of fruit and vegetable import market access requests. Two, *Oxalis hispidula* and *Philydrum lanuginosum*, were completed in response to new US detections. One, *Saccharum spontaneum*, was completed in response to a BRS request. Two were completed as part of ongoing safeguarding efforts.

**USDA 24: Provide timely scientific and technical support for emergency response and management**

PPQ must develop and maintain a high level of expertise to support preparedness in the areas of science, technical support, and technology transfer for rapid response efforts.

- The National Plant Protection Laboratory Accreditation Program accredits plant pathogen diagnostic labs and certifies diagnosticians within accredited labs to assist PPQ in screening samples in regulatory surveys. In 2016, NPPLAP developed, validated, and distributed proficiency test (PT) panels for HLB, *P. ramorum* and PPV, and administrated PT program for high consequence plant pathogens to support NPPLAP. Forty-three (43) HLB panels were distributed that resulted in the certification of 38 diagnosticians from 13 laboratories. For *P. ramorum*, 51 panels were distributed that resulted in 41 diagnosticians from 16 labs were certified. For PPV, 23 participants received panels and 20 diagnosticians from 10 labs have were certified.
- CPHST confirmed the presence of plant pathogens first in the U.S. (*Candidatus, Phytoplasma pini* and *Phytoplasma fraxini*-related, *Xanthomonas vasicola* pv *vasculorum*).
- Mobilized staff to support PPQ's emergency response to a new bacterial disease of corn in the United States. Conducted diagnostic testing and provided diagnostic expertise to additional testing labs. Developed forecasting models, trade, economic, risk and pathway analyses to determine alternative regulatory options, non-regulatory alternatives, areas of spread and impact.

- Supported PPQ emergency response to citrus canker detections in Texas, conducted NGS to determine that the strain primarily affected limes and conducting epidemiological studies to inform PPQ actions.
- Established an unmanned aircraft system (UAS) technical working group to coordinate pilot tests and operational implementation of UAS and develop strategic partnerships on this technology. Assemble a report on the requirements for certification of authorization, economic analysis, strategic sourcing, and information management in a full UAS program. The team is developing a roadmap for PPQ applications and investments in UAS technology for various regulatory programs. Completed successful pilot tests to demonstrate UAS applications, including release of sterile pink bollworm in eradication programs and survey for forest pests such as Asian longhorned beetle.

**Contributed to the long-term goal of eradicating European grapevine moth (EGVM) from the United States:**

- The EGVM Technical Working Group review of the 2015 and 2016 season data with program partners and delivered a report supporting the end of the EGVM quarantine.
- PPQ organized a post-eradication planning group and delivered an eradication plan in January 2016. This was publically posted when EGVM eradication was declared in August.
- A spatial analysis of the eradication program data was conducted that demonstrated the effectiveness of the program's 500 meter quarantine radius for survey and regulation.
- In addition to the target goals, S&T provided quality assurance technical support to ensure the

effectiveness of EGVM trapping.

- As a result of the eradication program, and with technical support from PPQ S&T, APHIS successfully completed one the agency's top 10 goals and declared eradication of EGVM in North America on August 18, 2016.

**CPHST contributed to the long-term goal of preventing citrus greening disease (*Huanglongbing*, HLB) from California:**

- Provided methods support to California program partners that increased their efficiency of *Tamarixia* (the parasitic wasp bio-control agent) production by 31 percent and decreased mortality of collected wasps to lower than 5 percent. The program produced >2.7 million *Tamarixia* and 300,000 *Diaphorencyrtus* in 2016. A new rearing facility that will start production in October of 2016 is expected to increase output by another 1.5 million *Tamarixia* per year.
- Evaluating bio-control sites, *Tamarixia* has been established at 92/100 evaluation sites in southern California, at 14/32 monitoring sites in western Arizona at some sites greater than 15 miles from release location indicating widespread establishment of *Tamarixia* is underway in Arizona. In California, *Diaphorencyrtus* recoveries have been made at 10/15 monitoring sites and recoveries have been made in all counties where releases have been made.
- Intensive sampling and molecular diagnostic testing for citrus greening disease or *Huanglongbing* (HLB) in Asian citrus psyllids (ACP) collected in Texas and California provided an opportunity to analyze spatial patterns and to locate infections of HLB earlier than plant sampling alone. Taking

advantage of the large amount of diagnostic data and spatial location data associated with the samples, CPHST analyzed the spatial pattern of the Ct-values across the landscape. This type of “hot spot” cluster analysis allows us to derive information from these samples and update the maps with potential HLB hot spots. Using this analysis, CPHST identified a potential “cluster” that resulted in finding the San Gabriel, California, area infections.

- CPHST evaluated new molecular methods for early detection and the use of root samples for detection. CPHST managed funds and provided field support for the development of canine HLB detection. In addition, administered funds for near-term solutions using enhanced survey tools, soil amendments, thermo-therapy and disease spread models.
- Accurate HLB diagnostics were assured by the NPPLAP Proficiency Test program ensuring lab capability of correctly performing the USDA Work Instructions for HLB diagnostic testing for USDA regulatory purposes; 34 participant analysts in 12 labs were certified in 2016 for HLB diagnostics.
- Developed and delivered a revised citrus nursery stock (CNS) protocol as well as two nursery stock facility reviews to improve exclusion and quarantine processes.

**Provide scientific methods to the fruit fly program:**

- DNA analyses of oriental fruit fly captures in California and Florida were identified as new introductions to exclude possibility of resurgent population or single high-risk pathway. Analyzed two fruit fly captures in south Texas as *Anastrepha* sp, most likely introduced from Mexico.

Analyzed Mediterranean fruit flies from four separate capture/interception events during 2016 using the Medfly Molecular Tool (MMT). Specimens from three of the events were interceptions from U.S. ports of entry. The fourth, representing an international collaborative effort, consisted of fruit flies captured in Aruba that were analyzed as per request by the Aruba Ministry of Agriculture.

- Completed confirmatory diagnosis of European cherry fruit flies, *Rhagoletis cerasi*. The specimens were provided by CFIA. The results support the presence of the fly in Canada. CPHST developed and delivered recommendations/protocols for detection trapping for the European cherry fly, which were used to initiate trapping efforts in NY and PA.
- Completed the sequencing of eight mitochondrial DNA genomes belonging to *Anastrepha distincta*, *A. ludens*, *A. serpentina*, *A. fraterculus*, *A. obliqua*, *A. suspensa*, *A. grandis*, and *A. striata*, all of which are considered species of economic importance. Sampling included the *A. ludens* black pupa strain currently being mass reared and released. The information will be used to improve species ID and pathway analyses tools.
- Completed a methods validation study to examine the performance of a SNP genotyping assay used to distinguish lab-reared TSL strains of Medfly from wild flies. This technology is the outcome of a collaborative project with USDA ARS to use Next Generation Sequencing for developing rapid diagnostic assays.
- CPHST conducted a Next Generation Sequencing study to characterize the utility of this technology on 384 individuals from previous fruit fly population genetic-based pathway analyses using highly variable genetic regions. The results will direct future efforts to understand the location of origin of

invasive pest species and demonstrate the potential of this technique to dramatically reduce cost and time of such analyses.

- In 2016 CPHST released comprehensive updates of the recorded host plants of *Bactrocera cucurbitae*, *B. dorsalis*, *B. tau* complex and *Anastrepha ludens*. These lists are used to generate Federal Orders for regulatory purposes in the implementation of area-wide emergency programs.
- Provided critical technical support to the Dominican Republic to address a major Mediterranean fruit fly outbreak that disrupted trade and was a potential threat to the United States.
- Fruit fly rearing: Developed several improvements in fruit fly rearing for sterile insect eradication programs that will improve quality and reduce costs:
  - Replaced torula yeast with toasted soy in larval rearing diet for Mediterranean fruit fly in Guatemala facility, resulting in cost savings of \$185,000/year.
  - Developed liquid diet to replace agar diet to feed adults; resulting in annual savings of \$150,000.
  - Transferred new black pupal sexing strain of Mexican fruit fly to Texas Mexfly program, resulting in 15 percent reduction in diet costs and significant reduction in equipment and space requirements.

**USDA 25: Improve communications between CPHST and its customers to assure market relevance**

CPHST aims to establish and maintain an effective dialogue with its customers to ensure development

activities are useful and applicable to customer needs.

- Through the National Clean Plant Network, S&T built and supports a PPQ-focused network of 29 crop-specific clean plant programs located in 23 centers in 17 States. The NCPN covers seven crops (fruit trees, grapes, hops, berries, citrus, sweet potato, and roses) engaging the work of 100 scientists. In 2016 the NCPN advanced the use and understanding of advanced technology such as next generation sequencing. Critical resources were provided to CA, FL, and TX in support of the citrus clean plant program quarantine facility and equipment needs of each State to ensure the availability of clean plants for replanting groves affected by citrus greening.
- In order to meet customer's needs, conducted a portfolio review of S&T geospatial and predictive modeling activities and developed a roadmap to provide a unified structure, goals, and roles and responsibilities for geospatial and modeling support.
- Updated export analysis templates and guidelines for training of additional staff in order to expand capacity for export market support. In FY 2016, S&T completed 38 analyses to support or maintain access to agricultural export markets.
- Published a biweekly S&T newsletter to enhance communications, with specific sections designated to answer anonymously submitted employee questions, provide EEO and diversity information, and a new section on safety and health issues.
- In addition to annual program review meetings, S&T's citrus health program initiated a listening session with major PPQ and industry stakeholders to better understand the issues that were impacting each citrus State. This session provided new perspectives that influenced new project

direction.

- PPQ participates in Commodity Sector meetings each year bringing representative from major commodities sectors such as citrus, potato, cotton, grain, apple, nursery, grapes, etc. that advise and provide constructive comments as to how PPQ and the sectors work together.

**USDA 26: Improve the CPHST work plan development and project prioritization process to assure high quality outcomes for customers / stakeholders**

CPHST will continue to develop a process with PPQ operations to produce mutually acceptable work plans that ensure appropriate product quality.

- Delivered employee training and guidance to all project leaders managing cooperative agreements to ensure high quality work plans and knowledge of administrative requirements.
- Provided quality management training and guidance to PPQ staff and State cooperators.
- In FY 2016, S&T leadership continued discussions with CPHST labs and held townhall video conference calls with S&T staff.
- Continued development of an enhanced prioritization tool for the Cooperative Agricultural Pest Survey program to improve the risk basis for rankings and therefore better utilize resources in all 50 States. In FY 2016, the predictive impact model was validated for arthropods by assessing 75

arthropods and comparing results to actual impact. Work on phase II, a model for likelihood of introduction continued.

- Provided oversight of 295 cooperative agreements with domestic and foreign researchers and organizations with a total value of over \$32,948,052. S&T receives Farm Bill Section 10007 funding totaling \$12,818,910 for agreement development, and in 2016, the distribution of those funds for cooperative agreements were: 64 percent academia, 5.7 percent international institutions, 3.1 percent industry, 0.6 percent non-profit entities, 10.4 percent state government, and 13.7 percent interagency agreements (ARS and FS). S&T provides administration and management of all *Huanglongbing* Multi-Agency Coordination Group funding.

#### 2.4.5 Downstream Outcomes



#### **Dispersal potential of the emerald ash borer parasitoid *Tetrastichus planipennis*.**

Emerald ash borer (EAB) is a devastating exotic pest which has the potential to extinct several species of ash trees from forests and natural areas in North America. Current USDA APHIS PPQ efforts to control and slow the movement of EAB populations are largely focused on developing biological control programs involving the release of parasitoid wasps from EAB's native range. It's therefore increasingly important to be able to track movement of released parasitoids and document their ability to find host

larvae in a variety of conditions. The CHPST Otis, MA laboratory in cooperation with SUNY College of Environmental Science and Forestry researchers recently completed studies demonstrating that the parasitoid *Tetrastichus planipennisi* tracks the movement of EAB as it moves along a linear path. Researchers investigated the movement of *T. planipennisi*, using traps placed parallel to a ~15 km greenway belt of trees in Central NY. Collections were made up to ~9km from the release site 1 year after the initial release. Additionally, in subsequent years parasitoids were collected away from the greenway in the middle of fields with no other ash trees nearby. The study demonstrated that *T. planipennisi* is well suited to build in numbers when its host density is high and to disperse long distances to find hosts when host population densities are lower. This information supports the EAB program efforts to mass rear and release *T. planipennisi* and the overall mission of Federal and State scientists to develop a biological control strategy that will protect the next generation of ash trees in eastern North America. (Photo by David Cappaert)



### **Eradication of European grapevine moth in California.**

The CPHST California Station and the CPHST Otis, MA Laboratory provided technical support for the notable eradication from California of European Grapevine Moth (EGVM), a severe pest of grapes. The first North American detections of EGVM were made in Napa County in 2010 where it was causing widespread damage to vineyards. After 6 years of cooperation with State and Federal scientists, industry representatives and regulatory officials, the last remaining EGVM quarantine areas of Napa and Sonoma

Counties in California was lifted and EGVM was declared eradicated from California on August 18, 2016. North America is now free from this pest. Technical support for quality assurance of EGVM detection trapping was provided by supplying laboratory colony moths for “seeding” traps in the field in California to test trapper accuracy and by analyzing pheromone blend and concentration in new and deployed lures. In 2016, spatial analysis of EGVM program data resulted in a better understanding of invasion pathways and made use of trap data to develop a more effective regulatory control program. Analysis so far has revealed landscape and environmental features that affected the EGVM invasion and demonstrated that the program’s use of 500 meter quarantine radius was an effective distance around a detection to survey and regulate. This protocol will be used by CDFG to maintain the eradication in CA. (Photo by Jack Kelley Clark: EGVM Adult.)



**Slowing the spread of the citrus greening disease through biological and chemical control of the Asian citrus psyllid.**

The Asian citrus psyllid (ACP) has invaded citrus-growing areas in the United States over the past decade and is an insect vector of the bacterium that causes citrus greening disease or Huanglongbing (HLB). A key component to an HLB management program is aggressive control of the insect vector ACP. CPHST California Station has partnered with State cooperators to rear and release *Tamarixia radiata* and *Diaphorencyrtus aligarhensi*, tiny parasitic wasps that have been imported into California from Asia to attack and control ACP populations. In 2016, Federal, State and industry program partners

increased their efficiency of *Tamarixia* production by 31 percent and the program is on track to produce >2.7 million *Tamarixia* and 300,000 *Diaphorencyrtus aligarhensis* per year. A new rearing facility will began production in October 2016 and is expected to increase output by an additional 1.5 million *Tamarixia* per year. *Tamarixia* has been established at 92/100 evaluation sites in southern California, at 14/32 monitoring sites in western Arizona at some sites greater than 15 miles from release location indicating widespread establishment of *Tamarixia* is underway in Arizona. In California, *Diaphorencyrtus* recoveries have been made at 10/15 monitoring sites and recoveries have been made in all counties where releases have been made. Chemical control strategies are also being supported through field and laboratory evaluations. Twelve pesticides were evaluated in the laboratory and 16 grower applied field treatments for ACP control (both conventional and organic insecticides). This Federal, State and industry partnership is critical to preventing ACP moving HLB from Mexico into commercial production areas in California. Additionally, the impacts of pesticides on *Tamarixia* for use in the ACP area-wide control program are being assessed. (Photo by Greg Simmons: Parasitized ACP nymphs)



### **Biological control of Asian Citrus Psyllid, the vector of citrus greening disease.**

The Asian citrus psyllid (ACP) has invaded citrus-growing areas in the US over the past decade and is a vector of a bacterium that causes citrus greening disease or Huanglongbing (HLB). A key component to a management program is aggressive control of ACP vector. *Tamarixia radiata* is a species specific

ectoparasitoid of the ACP that was imported from Pakistan after satisfying APHIS PPQ permitting requirements for field release in Texas.

In FY 2016, the CPHST Mission, TX Laboratory mass produced more than 1.75 million *T. radiata* per year for biological control of Asian citrus psyllids. *T. radiata* parasitoid adults were produced for releases in South Texas as well as to release on the Mexican side of the Texas and California borders. The parasitoids produced in our laboratory also served as inoculum for use in field insectary cages. Between 2013 and 2016, field cages installed at 125 sites yielded more than 1.51 million *T. radiata* per year for South Texas using this approach. This brings our cumulative total produced and released to more than 5 million per year. The field insectary cage technique has been transferred to researchers at the University of Florida, Immokalee, FL, the Puerto Rico Department of Agriculture, the University of California, Riverside and the California Department of Food and Agriculture, and most recently to the Texas Citrus Pest and Disease Management Corporation as a novel approach to enhance biological control efforts.

Before release of *T. radiata* began in South Texas in 2010, 43 immature psyllids per tree flush were found in citrus in residential areas. After biological control releases, the abundance of psyllids gradually decreased. In 2016, only 3.8 immature psyllids were found per flush, a reduction of 91.2 percent of the psyllid population.



**Hot spot cluster analysis of Asian citrus psyllid samples: predicting infected citrus host locations from diagnostic testing.**

Intensive sampling and molecular diagnostic testing for citrus greening disease or *Huanglongbing* (HLB) in Asian citrus psyllids (ACP) collected in Texas and California provided an opportunity to analyze spatial patterns and to locate infections of HLB earlier than plant sampling alone. ACP is a known insect vector of HLB, which is considered one of the most devastating citrus diseases because there is no cure for the disease. The quantitative Polymerase Chain Reaction (PCR) protocol used to test for the presence of HLB has very high sensitivity and specificity, and the PCR test provides a continuous measure of the amount bacteria present by recording a numerical value (Ct-value) indicating the presence of HLB in the sample. PPQ imposed a *regulatory threshold* on Ct-values, below which we can confirm the presence of HLB without question. However, due to the limits of detection of the qPCR assay, HLB cannot be reliably confirmed above this regulatory threshold with the current molecular techniques. It is unknown if samples above this threshold are false negative or true negative results and are referred to as inconclusive. Taking advantage of the large amount of diagnostic data and spatial location data associated with the samples, The CPHST Mission, TX Lab analyzed the spatial pattern of the Ct-values across the landscape to determine if there is an underlying biological process, such as clustering of samples around a known positive tree. This type of “hot spot” cluster analysis allows us to derive information from these inconclusive samples. PPQ continued to analyze new survey data as the results are received from state diagnostic labs and update the map with potential HLB hot spots. Using

this data from inconclusive sample information, the San Gabriel, California area infections were found after more intensive citrus tree sampling in an area around where an inconclusive psyllid sample was found. Analyses have also revealed significant space-time scales of pattern in the California psyllid data, such that inconclusive samples tend to cluster within 1.5 miles and 15 months of each other. Continuation of these analyses serve as early warning indicators for HLB positive trees and helps to target plant tissue (tree) surveys, saving state and federal resources, and helping the citrus industry identify infected trees sooner. This data is being provided to the TX and CA Departments of Agriculture to focus their financial and personnel resources more effectively.



### **New treatment options for the invasive Khapra beetle.**

The Khapra beetle (*T. granarium*) is a serious pest of stored products and is the only stored products pest that is currently quarantined in the United States. Khapra beetle larvae feed on a wide range of dry food products of plant and animal origin including cereals, dried fish, and museum specimens. It's regularly detected at United States ports of entry and occasionally in other areas such as warehouses, shipping containers, and private residences where efficacious treatments are required to assure that populations are completely controlled. The PPQ CPHST Otis, MA Laboratory has coordinated and sponsored a broad effort to evaluate new treatment options for Khapra beetle. Our partners included researchers at Kansas State University and the USDA ARS Center for Grain and Animal Health Research in Manhattan, KS. Khapra beetle is a quarantine pest in the United States so lab cultures have

not been available to use for treatment development until recently. Treatments of pyrethroid insecticides and insect growth regulators were evaluated for initial knockdown and residual efficacy in applications on concrete, wood, painted-wood, vinyl flooring tile, and metal surfaces to simulate the wide range of environments that Khapra beetle may be found in the field. Both small and large *T. granarium* larvae were exposed with provision of a food source on the treated surfaces and residual assay was conducted up to 12 weeks post-treatment time. Data from this project will support new treatment options and guidelines for Khapra beetle treatments added to the APHIS Treatment Manual that is used by DHS CBP and PPQ officers at ports of entry and infested structures such as warehouses.



#### **Identifying a new treatment for airplane cargo holds.**

The PPQ Center for Plant Health Science and Technology (CPHST), Otis, MA Laboratory tested and identified a suitable replacement aerosol treatment used for hitchhiking insects in cargo holds. The sole previous treatment became unavailable when the manufacturer chose not to renew the EPA registration, leaving APHIS PPQ and DHS Customs and Border Protection Port Officers with only a limited supply of existing treatment aerosol cans. An efficacious replacement was needed for PPQ and CBP officers involved with hitchhiking insects in cargo and for Japanese beetle mitigation in aircraft cargo holds. Schedule T409 in the APHIS [Treatment Manual](#) was updated and a treatment table was extensively reworked to include the new treatment, Callington 1-Shot™ aerosol product (T409-b-3). Scientists from CPHST Raleigh, NC, CPHST Otis Lab, the CPHST Treatment Quality Assurance Unit, the PPQ

Treatment Manuals Editor, DHS CBP, the California Department of Food and Agriculture, and other regulatory officials, worked together to review and provide relevant input that enabled the new treatment as an alternative to be added to the APHIS Treatment Manual in a timely manner to assist operations at points of entry.



**Sharing data on rearing and unmanned aircraft system release of sterile Naval Orangeworm; helping to develop international partnerships.**

The Naval Orangeworm is a serious pest that threatens nut crops in California. The CPHST Phoenix, AZ Laboratory has developed a sterile insect rearing strategy to control this pest. USDA APHIS and its unmanned aircraft systems industry cooperator recently shared advanced methods and techniques related to the use of sterile insect technology (SIT) for Lepidoptera control and SIT insect release via Unmanned Aircraft Systems (UAS) at a joint FAO/IAEA Research Coordination Meeting. This meeting, "Improved Field Performance of Sterile Male Lepidoptera to Ensure Success in SIT Programmes," brought scientists from United Nations member states together to discuss technical challenges, hurdles and accomplishments related to their respective sterile lepidoptera programs. Anchored on the success of the Area-Wide Pink Bollworm Eradication Programs, as well as the development of advanced UAS capabilities related to rapid response in SIT programs, USDA APHIS presented advancements in rearing methods related to a new pest, Navel Orangeworm (

scientists from around the world are being fostered with USDA APHIS to advance mass rearing and release programs. (Photo: Naval Orangetworm photo from USDA ARS)



**Combined vacuum and steam as an emerging phytosanitary treatment of ceramic tile and marble.**

Since 2011, the CPHST Otis, MA laboratory has partnered with Virginia Tech University to develop vacuum steam technology as a methyl bromide alternative treatment for a range of durable commodities with phytosanitary pest issues. One of the more successful applications has been on commercial ceramic tile and marble for hitchhiking pests, particularly snails. Invasive Mediterranean snails are generally introduced into the United States via one of two pathways, either military transport containers shipped from overseas installations or in commercial tile and marble shipments. Tile and marble are generally packaged in corrugated cardboard boxes that are stacked on pallets, then shrink wrapped for protection during shipping. It's common practice for tile manufacturers and distributors to temporarily store the palletized tile in outside locations where invasive snails gain entry under the protective wrap. Vacuum and steam trials conducted at Virginia Tech in a chamber mounted on trailer demonstrated complete effectiveness against field collected invasive snails *Certhuella cisalpina* and *Eobania vermiculata* that were artificially seeded within a unit load of tile. Various measures to assess tile and packaging integrity post-treatment were also evaluated to insure no detrimental effect to shipped materials due to treatment. The Otis laboratory staff are currently developing a vacuum and steam

treatment schedule recommendations for inclusion in the APHIS Treatment Manual. The effects of vacuum steam on pests and pathogens of hardwood logs and bamboo is currently under examination, as are discussions with industry to promote commercial development of this technology.



**Using a super food-based attractant to get the last giant African snail.**

Considered the most damaging snail in the world, the Giant African Snail (GAS) also carries a parasitic nematode that can lead to meningitis in humans. Since 2011, PPQ and the Florida Department of Agriculture and Consumer Service (FDACS) have been fighting to eradicate the Giant African snail from South Florida. Economic losses noted in a 2005 publication from no control action were estimated to be \$53 million per year. Their efforts have dramatically reduced the populations, but the trick is now to get those last snails that remain protected between fences, under porches, or behind debris piles.

Worse is that laboratory studies have shown that a single snail can produce viable offspring. The last GAS outbreak in Florida was from only two snails brought illegally from Hawaii so assuring that the last snail is gone is critical. In a collaborative effort funded through the Farm Bill, scientists from CPHST Miami Lab, FDACS, the University of California, Riverside, Oregon State University, and the University of Hawaii have discovered and tested food-based attractants such as rabbit or cat food distillate and papaya oil to effectively lure those last snails from hiding (Fig. 1). In replicated field studies (three in Miami and six in Hawaii), the plots with attractants had significantly (50-80 percent) more snails than in the control plots without the attractant. A newly discovered population of snails in

South Florida provided an opportunity for FDACS eradication program field staff and CPHST to work together to develop effective methods to begin deploying the lures on a large scale (Fig. 2). In a test area that had gone several days with no snail detections, field staff applied lures combined with the metaldehyde pesticide bait. As a result, many additional small young snails were detected. The project team will continue to optimize the lure to provide a tool to attract and kill the remaining low numbers of snails. PPQ is currently reviewing NEPA requirements for use of the attractant. This technology is being transferred to the FDACS South Florida Eradication Program and PPQ is conducting outreach in FY 2017 to GAS programs in the Caribbean that are attempting GAS eradication. (Photo Credit: R. McDonnell, UC Riverside Giant African snails highly attracted to steam distillate of cat food).



A.



B.

### **Identification of port intercepted wood boring beetles informs pathway of exotic forest pests.**

Through an ongoing cooperative project with DHS Customs and Border Protection (CBP), APHIS PPQ Field Operations and Xavier University, the CPHST Otis, MA Laboratory has been identifying wood boring insects intercepted at ports of entry and improving molecular diagnostic capabilities for these taxa. Despite the regulations outlined in the International Standards for Phytosanitary Measures No. 15 (ISPM 15), an International Phytosanitary Measure adopted by the International Plant Protection Convention (IPPC), solid wood packing material (WPM) continues to act as an important pathway of introduction for exotic wood boring insects. Live larvae of potentially destructive exotic wood borers are frequently intercepted at U.S. ports of entry in “treated” WPM. Larvae intercepted in quarantine often

remain unidentified beyond family level because immature stages are difficult to identify using morphological characteristics. In addition, DNA barcodes (a very short genetic sequence from a standard part of the genome) are not available for many exotic wood borer species. As a result, valuable information is lost about risk pathways and failure of phytosanitary treatments for particular genera and species.

In the last 4 years, wood borer larvae intercepted during agricultural inspections at 11 U.S. ports have been sent to the containment facility at Otis Laboratory for rearing to the adult stage. Upon emergence, adult specimens are sent to the Systematic Entomology Laboratory for identification. DNA barcode sequences are obtained for each specimen, regardless of life stage reached. Once barcode sequences from identified species are submitted to a database (e.g., GenBank, BOLD [Barcoding of Life Database]), any life stage of that species can be identifiable by matching barcode sequences with existing records. To date, DNA from 805 beetle and wood wasp specimens in 3 families were evaluated of which 499 specimens were identified with high probability to genus level and 235 specimens to species level. Of 28 cerambycid genera intercepted and identified, 7 genera (*Anoplophora*, *Chlorophorus*, *Hylotrupes*, *Monochamus*, *Phoracantha*, *Tetropium*, *Trichoferus*, *Xylotrechus*) are exotic species at high risk of becoming invasive or are already invasive in North America.

Data from this project has been provided to the CPHST Pest Epidemiology and Risk Analysis Laboratory (PERAL) in Raleigh, NC as a WPM risk analysis tool. Evidence was provided to IPPC (International Plant Protection Convention) and NAPPO (North American Plant Protection Organization) on intercepted high-risk species to attempt to foster compliance with ISPM-15. Species identifications were made available to DHS CBP via the PPQ Pest Interception Database (PestID) that provides data to CBP and PPQ Officers for targeted inspection of WPM. This data was also made

available to the PPQ Cooperative Agricultural Pest Survey (CAPS) for targeting species and survey sites for woodborers of quarantine concern during State surveys. Finally, images of larvae are being used to develop an online interactive tool to identify intercepted cerambycid beetle larvae using high-quality digital photographs, and for a web-based interface to identify “unknown” cerambycid beetles using a DNA sequence-based search tool. (A) Adult Asian longhorned beetle reared from a larvae intercepted at in Seattle, (B) Cerambycid gallery in WPM intercepted at port of Long Beach, CA.



**PPQ assist states in surveying for a new corn disease and provides assurance to international trade partners.**

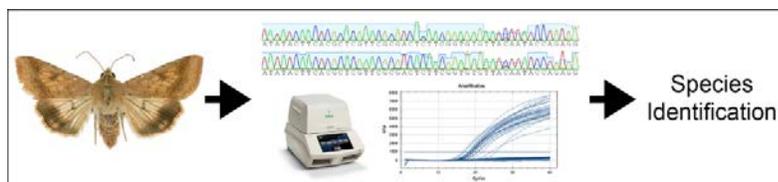
PPQ was notified in late 2014 of a new corn disease with a difficult-to-identify causative agent. Experts were consulted in 2015 and the eventual diagnosis was ‘bacterial leaf streak of corn’ caused by *Xanthomonas vasicola* pathovar (pv.) *vasculorum* (Xvv). Xvv has a rich and confusing taxonomic history that includes the pathogen *Xanthomonas campestris* pv. *zeae* (Xcz), the causal agent of bacterial leaf streak of maize), that was isolated from maize and previously found only in southern Africa. Although Xcz had not been discussed in scientific literature for over 20 years and did not have a formally accepted name, it could be distinguished from other Xvv strains using molecular tools. Molecular tools are also the only way to distinguish Xcz from the closely related endemic sorghum pathogen, *Xanthomonas vasicola* pv. *holcicola* (Xvh). Physiological, pathogenicity, and serological tests can only be used to diagnose to the genus and species level, however a molecular test to diagnose

to the subspecies level of pathovar was needed for accurate confirmatory diagnostics. The PPQ CPHST Beltsville, MD, Laboratory devised a confirmatory protocol using sequence analysis of multiple genes to specifically identify the U.S. isolates as an Xcz-related subgroup of Xvv, and different from endemic Xvh strains. The Beltsville Laboratory also: optimized a screening assay developed by collaborators at Colorado State University; wrote protocols that included corn leaf sampling and extraction instructions with pictorial aides; and distributed the protocol along with positive and negative controls to State and Federal diagnostic labs in the Midwestern States. PPQ worked with State agencies to deploy surveyors in 12 States covering 338 different counties that collected over 1,500 samples for screening to understand the distribution of this pathogen. Over 100 presumptive positive samples were sent to PPQ CPHST Beltsville Laboratory for official confirmation, and the results were compiled into a document prepared by the New Pest Advisory Group (NPAG) of the CPHST Pest Epidemiology and Risk Analysis Lab. The NPAG report provided advice to APHIS PPQ management on Xvv reporting to international trading partners. Additionally, the CPHST Beltsville Laboratory performed whole genome sequencing on a few of the U.S. Xvv isolates and the data is being shared with a leading authority on Xvv taxonomy, Dr. David Studholme at the University of Exeter, UK, to develop a more accurate taxonomy of this pathogen and its relatives. The sequence data is being used by the Beltsville Laboratory to develop new molecular diagnostics to distribute to State programs and domestic and international scientists to monitor and prevent further spread of this disease.



**Identification of boll weevils to support cotton production.**

Since the early 1920s, the boll weevil has been a major economic pest of cultivated cotton in the United States. To support cotton production, eradication programs have been directed at boll weevil populations in the southern United States and northern Mexico. These programs have been successful for many areas, but reintroduction of new weevil populations is always possible. Early detection and identification of weevils is an important part of boll weevil control. Accurate identification of trapped weevils can sometimes require specialized morphological and DNA analysis. In FY 2016, the APHIS PPQ CPHST Mission, TX, Laboratory provided DNA analysis of weevils to distinguish between commercial and wild cotton boll weevil variants. These methods have been published and were presented to entities working to eradicate the weevil in the United States and Mexico. The results of numerous diagnostic assays conducted at the Mission Lab have provided cotton programs in Texas, New Mexico, Arizona, and the Mexican States of Chihuahua, Durango, Coahuila, Sonora, Baja California and Tamaulipas with information that has helped maintain areas in the Southwestern United States free from boll weevil. More recently, methods for the source estimation of boll weevil captures have been developed in collaboration with the Texas Boll Weevil Eradication Foundation Inc. and researchers at Texas A&M, AgriLife using Next Generation Sequencing. These newer methods and technology are being evaluated and may help trace future captures to source population, thus aiding development of more effective eradication strategies in the United States and Mexico. (Photo by Florida DPI, FDACS, Bugwood.org)



### **Advanced molecular diagnostics for the Old World bollworm.**

The Old World bollworm is a moth that can attack and damage more than 180 plant species including cotton, corn, peanut, sorghum, and tomato. This moth was not thought to be present in the New World (i.e. the Americas) until 2012, when specimens were identified from an outbreak that started in Brazil. Since that outbreak, new records have been reported in North and South America and the Caribbean. This species is difficult to diagnose because it is nearly identical in appearance to a common native moth, the corn earworm. These two pests also attack similar crops, further complicating detection of the Old World bollworm. Scientists from the APHIS-PPQ-CPHST laboratories in Fort Collins, CO, and Mission, TX, and USDA-ARS Southern Insect Management Unit have been developing new methods to identify these moths. In FY 2016 APHIS verified molecular techniques to diagnose the moths based on slight differences in DNA. These published technologies have been developed into protocols for diagnosing a single moth and were presented to State and Federal scientists at a strategic planning meeting for Old World bollworm held in Florida in 2016. The methods have been used by APHIS in 2016 to diagnose moth larvae collected during a survey of Puerto Rico in 2015 and to identify moth interceptions at U.S. borders to confirm safe trade practices. The APHIS scientists are currently testing new technologies to make it possible to diagnose hundreds of moths in a single reaction. These methods development and diagnostic activities are helping to exclude invasive exotic species from the United States in order to protect crops and natural resources.



**Developing and sharing new resources to accurately diagnose exotic fruit flies.**

Fruit flies in the family *Tephritidae* pose a significant threat to U.S. production and trade of fruits and vegetables. The larvae of fruit flies feed and grow within host plants causing direct damage. Some exotic fruit flies such as the oriental fruit fly can develop in hundreds of plant species. To minimize the risk of an accidental introduction and establishment of exotic flies, PPQ coordinates Fruit Fly Exclusion and Detection programs. The APHIS PPQ CPHST Mission, TX Laboratory develops and tests molecular methods to identify fruit flies. Correct identification of a detected fly is necessary to develop an effective response based on trapping strategies and pest management decisions. In FY 2016, the Mission Lab verified and enhanced identification resources for several important pests. New DNA sequence resources to diagnose the Mexican fruit fly, Caribbean fruit fly, and West Indian fruit fly were published and released for use by state, federal and international stakeholders. In addition, new DNA profiles were generated for the oriental fruit fly. These profiles were used to compare flies trapped in Florida and California to populations intercepted at borders or collected offshore. The oriental fruit fly project is a collaborative effort between APHIS and States to recognize and shut down high risk pathways. In FY 2016, the new resources were used to confirm that independent outbreaks of oriental fruit fly in California and Florida in 2016 were the result of new introductions, not failure of eradication efforts in 2015. In February 2016, the Mission Laboratory and CDFA co-hosted a meeting in Sacramento to share new resources and techniques. The meeting included participants from APHIS, CDFA, ARS, Florida DPI, and scientists from several universities. (Photo by IAEA)



**Increasing the identification accuracy of the fungal genus *Phytophthora* International collaboration led by APHIS PPQ.**

The plant fungal genus *Phytophthora*, currently containing 163 described species, is considered as one of the most important genera of fungal plant pathogens. Numerous species are reported to cause diseases of high economic impact to crops, ornamentals, forestry and natural ecosystems worldwide. Many species are of regulatory concern for the United States and many other countries and although considerable progress has been made in the last 15 years in aspects of morphological and molecular identification of species, accurate identification remains a major challenge for scientific laboratories. Since 2012, the PPQ CPHST Beltsville, MD, Lab has led the development and implementation of a new tool, *Phytophthora* ID in collaboration with the Center of *Phytophthora* at University of Murdoch in Australia, the World *Phytophthora* Collection, at the University of California Riverside, and the CPHST Fort Collins, CO Lab, Identification Technology Program (ITP).

The CPHST lab has pioneered the use of Ex-types cultures (cultures derived from the type specimen held in a herbarium) of all published species to document the morphological and molecular data for the genus *Phytophthora*. These data are already being used for multiple projects including the *Phytophthora* ID, an online identification resource packed with resources including a Lucid Key, Tabular Key, and Sequencing Analysis tools. When completed *Phytophthora* ID will

contain hundreds of microphotographs, sequences, factsheets for each of the described species, as well as an image gallery, glossary, and numerous links to key worldwide resources. As part of the collaboration project outreach activities, a workshop presenting *Phytophthora* ID was conducted by two scientists from the CPHST Beltsville Laboratory at the 2016 American Phytopathological Society meeting in Tampa, FL, August 2016. This event marked the beginning of beta testing for the identification resource by participants from seven countries that attended the event. An abundance of positive feedback was received from the participants related to its use by industry labs, the increase in accuracy of *Phytophthora* information and genetic data compared to current data in NCBI GenBank, and its global benefit to new researchers, regulatory officials, and industry, and to experts in the field. The *Phytophthora* ID resource is expected to be released for use by the scientific community in spring of 2017.



### **Next generation sequencing benefits citrus canker surveys in Texas.**

Asiatic citrus canker (*Xanthomonas citri* subsp. *citri* (Xac)) is one of the most devastating citrus diseases for which the CPHST Beltsville Laboratory provides support to the PPQ Citrus Health Response Program (CHRP) by conducting confirmatory testing and developing fit for purpose diagnostic methods. In the fall of 2015, an outbreak occurred in Cameron County of Southern Texas. The first samples from Texas arrived to the Beltsville lab on Oct 20, 2015 and confirmed as *Xanthomonas citri* subsp. *citri*.

More than one hundred and eighty (180) samples were received for confirmatory testing and pathotype determination during the first quarter of FY 2016.

Three citrus canker pathotypes are currently known: the Asiatic citrus canker (Xac A) with world-wide distribution and host specificity that includes all important commercial citrus, and two minor pathotypes, Xac AW and A\*, that infect mainly lime. Xac A is widely distributed in Florida and under Federal quarantine and is also found in Louisiana since 2013. Field observations for the Cameron County, Texas outbreak suggested limited host specificity to Mexican lime, characteristic to Xac AW or A\* pathotypes. Because citrus canker pathotypes differ in their host range, determining the pathotype assisted the Texas PPQ CHRP and Texas Department of Agriculture to make an informed decision on their response type and to utilize their resources more effectively through targeted surveys. The Beltsville team was challenged to apply appropriate diagnostic methods to confirm the pathotype from several methods in existence including new but non-validated serological and molecular methods, and they were able to rule out the Xac A (Asian) pathotype. Since existing methods could not positively determine pathotype of the TX isolates as AW or A\*, CPHST sponsored a joint effort with the University of Florida using Next Generation Sequencing (NGS) of the whole genomes of three (3) of the Texas citrus canker isolates with limited host range from Texas (two from Mexican lime and one from kaffir lime). The sequence was completed and analysis determined the three isolates to be *Xanthomonas citri* subsp. *citri* pathovar AW (Wellington) based on the comparison with sequences available in the Gen Bank. These results were provided to the PPQ Texas Field Operation office and the Texas Department of Agriculture (TDA) in late August 2016. Based on this determination, TDA is removing the infected trees, a measure that will help protect small Persian lime groves across the lower Rio Grande Valley. In addition to informing Federal and State regulatory operations, these results demonstrate the potential of the application of NGS in pathogen identification and differentiation for

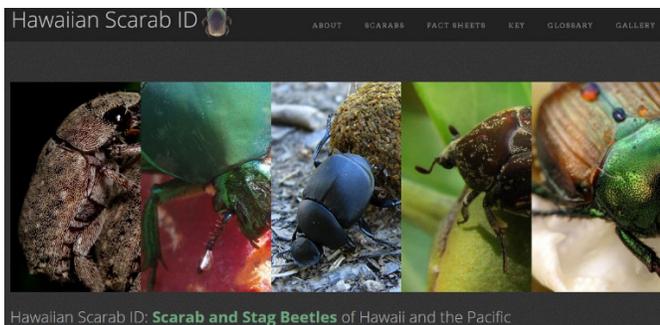
phytosanitary diagnostics. NGS, massively parallel, or deep sequencing are related terms that describe a DNA sequencing technology which has revolutionized genomic research. NGS information could lead to more rapid development of new molecular diagnostic assays, methods, and tools. The Beltsville lab is using the information from this study to select appropriate sequence targets for developing pathotype-specific molecular tool for *Xac* differentiation. (Photo by University of FL)



### **Improved mass-rearing of Mexican fruit fly for sterile release in Texas citrus.**

Tephritid fruit flies (Diptera: Tephritidae) include a number of species that are major agricultural pests of worldwide economic importance. One such pest is the Mexican fruit fly (Mexfly), *Anastrepha ludens*, which is established in Mexico and is regularly intercepted in citrus growing areas of the lower Rio Grande Valley of south Texas along the U.S./Mexico border. An ongoing sterile insect release program for the Mexfly helps to ensure the fly doesn't become established. Critical to the success of this program is the ability to efficiently and cost effectively mass-rear sterile Mexflies. In August 2016, CPHST fully transitioned to using a new black pupal sexing strain (Family 10) of Mexfly developed in Guatemala to supply the Texas release program. In this strain, male pupae are black while female pupae are brown. This color difference allows for the use of an optical sorter by program managers who are able to sort the pupae by sex and release predominantly sterile males. The male-only strategy maximizes the biocontrol of introduced wild Mexfly populations by removing any chance that the sterile released flies will simply mate among themselves. As a result, the all-male strain more specifically

targets wild females for mating, helping to assure most females aren't fertilized and don't produce offspring. This in turn leads to a more rapid decline in the wild fruit fly population and ultimately eradication. The new black pupal strain shows an improved genetic stability during the rearing process as well as an optimized production of eggs and larval recovery. Its use in the rearing operation introduces significant savings compared to the previous strain including: a 20-percent reduction in the number of eggging cages needed; a 10- to 15-percent reduction in the number of diet trays that need to be prepared; a 15-percent increase in the number of males produced; and a 15 percent savings in diet ingredient costs. Other improvements in the rearing process that were introduced in 2016 include a betadine egg rinse and egg-laying panel rinse. Betadine is a broad-spectrum germicide and a long-term microbiostatic that kills problematic microbes without effecting the quantity or quality of the Mexfly production. After extensive evaluation and validation at large scale production, CPHST introduced the use of toasted soy as a replacement for 25 percent of the torula yeast used per year in the larval rearing diet of Mexfly. This improvement to the larval diet has stabilized and improved fly quality, increased overall production, and provided an estimated yearly recurrent cost savings on dietary ingredients of over \$185,000 per year. These cost savings and increased quality will benefit PPQ and State program operations as well as international rearing operations.



**New pest identification apps, websites, and images released for PPQ and PPQ partners' toolbox.**

Efficient and accurate identification of plant pests is an essential component of our Nation's agriculture safeguarding effort. To assist this effort, PPQ's Science & Technology, CPHST Identification Tools Program (ITP) develops and delivers technologically based, scientifically valuable pest identification resources for PPQ and its partners. CPHST works closely with international and national scientists to digitally capture scientific expertise for incorporation into all new resources. Each resource is custom-designed for specific clients and stakeholders depending on their location and their specific safeguarding responsibilities. Resources are created for stakeholders leading the safeguarding efforts at PPQ's first line of pest defense (off shore), second line of pest defense (ports of entry), and third line of pest defense (domestic surveillance). During 2016, we saw significant advances towards CPHST's ongoing challenges associated with delivering user-friendly identification resources to PPQ and its stakeholders.

- Two new mobile identification apps (*Grasshoppers of the Western U.S.* and *Hawaiian Scarab ID*), for iOS and Android devices, were released in 2016 to support PPQ's domestic partners' longstanding need for field-based products for pest screening (visit the [App Store](#) or [Google Play](#) to download the apps). Ten previously released CPHST mobile apps for iOS and Android devices had significant updates in 2016, and the iOS apps were optimized to run on iPads. Since the release of CPHST's first Lucid Mobile apps in 2014, there have been 18,877 downloads recorded.
- The University of Georgia and CPHST released a significant upgrade to the end-user interfaces for four of [Bugwood's](#) image sites. Forestry Images, Insect Images, IPM Images, and Weed Images have a new look with added navigation and functionalities to support sharing of images. Users are now offered powerful filtering capabilities, the ease of requesting and managing their image permissions, and the ability to develop personalized image collections for presentations, sharing, and embedding into other sites. All four sites now have a responsive design — so they provide optimal

viewing and interaction experiences across a wide range of devices including desktops, tablets, and mobile phones. Today, with over 249,000 images, [images.bugwood.org](http://images.bugwood.org) is considered the primary source by governmental agencies, NGOs, and academic institutions for images associated with natural resources and agricultural pests. In 2016, CPHST released a significant upgrade to its identification resource website (<http://idtools.org/>). The website has a new look and feel, along with expanded functionality to find the right resources for specific identification needs. The “Find ID support” page includes descriptions and links for all of CPHST’s tools, apps, and screening aids. The site also includes descriptions for all the different types of products it delivers to assist PPQ and its partners with pest identification. The new home page features selected collections of external validated resources, as well as articles announcing product releases and other items of interest related to plant pest identification.

- The website [\*Hawaiian Scarab ID: Scarab and Stage Beetles of Hawaii and the Pacific\*](#) was released in 2016 in response to recent introductions of invasive scarab species in Hawaii, such as the coconut rhinoceros beetle (*Oryctes rhinoceros*). Designed for both non-specialists and specialists, *Hawaiian Scarab ID* was scoped to assist individuals with distinguishing scarab pests from scarab non-pests. The website, developed in cooperation with experts at Wichita State University, features illustrated morphology guides, an image gallery, fact sheets, and a Lucid key.



**Geospatial technology and predictive modeling tools to support trade activities, domestic pest surveillance, and emergency response.**

The PPQ Center for Plant Health Science and Technology (CPHST) provides new and innovative tools to analyze data, identify patterns of pest behavior, and inform risk. With a diverse team of internal and external subject matter experts, CPHST uses geospatial analytics and predictive modeling methods to assist decisionmaking for PPQ plant pest programs as described below for FY 2016:

**Understanding how international trade impacts agricultural plant health.** CPHST currently leads an effort to analyze the risk associated with imported goods and passenger inflow. The “**Port Environments**” project is developing a suite of spatial data representing highest risk areas and associated pathways, along with a bioeconomic model to support resource allocation in those areas. Integrated products include a data driven tool identifying areas at highest risk for pest introduction based on wood packaging material and an integrative spatiotemporal risk model for fruit fly introduction in the United States. These tools assist PPQ resource allocation and that of our stakeholders.

**Supporting domestic pest programs.** Proactively monitoring and responding to an exotic pest is central to any regulatory Federal and State pest program. To assist Federal and State surveillance and resource planning, several products were developed. Likelihood of detection risk models were delivered for *Lymantria dispar dispar* (European gypsy moth) and *Agrilus planipennis* (emerald ash borer). To support the Cooperative Agricultural Pest Survey (CAPS) by States in cooperation with PPQ, several pest phenology and climate suitability models were initiated, with a focus on *Dendrolimus pini* (pine tree lappet moth), *Epiphyas postvittana* (light brown apple moth), *Helicoverpa armigera* (Old world bollworm), *Monochamus alternatus* (Japanese pine sawyer beetle), *Platypus quercivorus* (oak ambrosia beetle), and *Thaumatotibia leucotreta* (false codling moth). This information assisted State partners as to when and where to deploy surveillance assets.

**Providing rapid analytical support to emergency response.** CPHST analysts use quantitative methods to assist PPQ decisionmakers when responding to an emergency from a pest incursion. Recently, CPHST delivered a forecasting model to determine environmental suitable areas that support establishment and spread of *Xanthomonas vasicola* pv. *vasculorum* (Xvv), the bacteria causing bacterial leaf streak of corn. Output from this model informed surveillance activities by State and Federal surveyors in Midwestern States and assisted USDA and the industry in understanding potential economic impacts to the American corn industry.

CPHST analytical support to Federal and State programs is strengthened by the development of SAFARIS (Spatial Analytic Framework for Advanced Risk Information Systems), a comprehensive structure that houses analytical data, tools, and deliverables. The integration of this framework into the CPHST workflow provides a comprehensive and efficient analytical strategy that benefits internal staff as well as the PPQ stakeholder base regarding plant pests.



**Using a new pest prioritization model to target the highest impact pests in exotic pest detection surveys.**

The PPQ Cooperative Agricultural Pest Survey (CAPS) program conducts surveys in the United States targeted at exotic plant pests, diseases, and weeds identified as threats to U.S. agriculture and/or the environment. The PPQ CPHST Ft. Collins, CO laboratory evaluates new pests to determine which are of

the greatest threat to the United States. In 2016, the Ft. Collins laboratory used a new pest prioritization model, the Objective Prioritization for Exotic Pests (OPEP) model, created by the CPHST Plant Epidemiology and Risk Analysis Laboratory (PERAL). The predictive model is based on a series of questions which require objective, documented evidence from the scientific literature to answer. Each question is scored based on its power to predict impact, and the final result is given as high, moderate, or low impact. The model has been in development for several years, and 2016 was the first year that the model was used to evaluate new pest threats and current pests on the CAPS Priority Pest List: Pests of Economic and Environmental Importance. This list is one of two Priority Pest Lists that form the foundation of survey activity for the CAPS program. In 2016, two new separate models, one for arthropods and one for plant pathogens, were used to evaluate 38 pests suggested as new and 53 pests that were currently on the pest list. CPHST then performs another step of analysis for each of the high-ranking pests, by evaluating: (1) the ease of detection of the pest; (2) the ease of identification; and (3) the available expertise and diagnostic/identification capacity for the pest. Pests must have both survey and diagnostic/identification methods available to be added to the final pest list. Annually the Priority Pest Lists are shared with the team for Farm Bill Section 10007 Goal Area 3 “Pest Identification and Technology Enhancement.” The specific needs (e.g., a lure for a specific moth target) are documented in the Farm Bill guidance document that is posted on the Farm Bill website during the suggestion open period. Farm Bill suggestions that specifically address these areas of need are rated higher. The following pests had a significant likelihood of having a high impact in the United States and also had survey and diagnostic/identification methods and capacity available and were added to the FY 2017 CAPS Priority Pest List: Pests of Economic and Environmental Importance: *Anguina tritici* (Wheat gall nematode), ‘*Candidatus* Phytoplasma phoenicium’ 16SrIX-B (Almond witches’ broom), *Eurygaster integriceps* (Sunn pest), *Laodelphax striatellus* (Small brown planthopper), *Thaumetopoea pityocampa* (Pine processionary moth), *Cucumber green mottle mosaic virus* (CGMMV), and *Groundnut bud*

*necrosis virus* (GBNV). Finally, to educate the CAPS community of Federal and State stakeholders regarding how results of the new model impacted the final pest list, the Ft. Collins Lab developed support documents and conducted outreach to the National CAPS Committee and to the National Plant Board at their annual Central and Eastern Plant Board meetings. CPHST is now developing support products for these new pests, including pest datasheets, approved survey and diagnostic methods, and pest host maps. These are made available - [CAPS resources](#) - to our stakeholders on the APHIS PPQ website.

## **2.5 VETERINARY SERVICES (VS)**

[http://www.aphis.usda.gov/animal\\_health/index.shtml](http://www.aphis.usda.gov/animal_health/index.shtml)

### **2.5.1. Mission Statement**

As the recognized animal health leader and trusted partner, Veterinary Services safeguards the health of animals, people, and the environment. VS's authorities derive from the Animal Health Protection Act and the Virus Serum Toxin Act. VS integrates One Health principles with USDA business objectives by contributing leadership, expertise, infrastructure, networks, and systems to collaborate effectively with local, State, tribal, national, and international partners. Its comprehensive and integrated on-farm surveillance activities provide VS the capability to achieve national goals for animal disease prevention, detection, and early response.

### **2.5.2. Nature and Structure of Program**

In FY 2013, VS was organized into policy and permitting staffs, a field force, and three science centers, described below:

#### **The National Veterinary Services Laboratories (NVSL)**

The mission of NVSL is to safeguard U.S. animal health and contribute to public health by ensuring that timely and accurate diagnostic laboratory support is provided directly or by its coordination of the nationwide animal-health diagnostic system. NVSL accomplishes its mission through:

- Performing diagnostic laboratory testing for Veterinary Services' program diseases and for suspected outbreaks of foreign animal diseases;
- Serving as the U.S. national and international reference laboratory for animal disease diagnosis by providing unique veterinary diagnostic capabilities, providing other diagnostic laboratories with animal disease information, technical guidance, reagents and reference materials;
- Providing national leadership in coordination of the National Animal Health Laboratory Network (NAHLN) and emergency laboratory response by training State, university and foreign laboratory personnel; providing proficiency testing; and developing improved diagnostic technologies;
- Preparing for and responding to animal health emergencies and emerging threats to animal agriculture including threats to the poultry and aquaculture industries by being able to conduct and/or support diagnostic testing in an outbreak environment.

Among other potential TT activities, NVSL develops and validates assays, and manufactures and distributes over 500 biological reagents to support veterinary diagnostics, many of which are not available from any other source.

Before a test is utilized by Veterinary Services for disease control or surveillance, it must be validated for that purpose. Samples for test validation for program diseases such as brucellosis and tuberculosis are in serum and tissue banks generated and maintained at the NVSL. These samples are made available to commercial kit manufacturers for their initial validation, and additional test validation is conducted at

the NVSL before the results are submitted to the USAHA Scientific Advisory Committees. This is in addition to any testing for licensure required by the Center for Veterinary Biologics.

The NVSL is also involved in the development and validation of assays used to detect diseases that are foreign to the United States. Some of these assays are utilized in the reference laboratory as confirmatory tests, while others are deployed to the NAHLN laboratories and utilized in surveillance programs.

Identification, feasibility testing, development, optimization and validation of new assays and/or technologies are all accomplished within the NVSL. The NVSL staff collaborates with and provides scientific advice to other Federal and State Government agencies that are also developing new assays and technologies, and NVSL scientists partner with other reference laboratories around the world to obtain diagnostic specimens from naturally infected animals. These collaborative efforts result in enhanced expertise at the NVSL and in reference collections that are available for assay development and validation.

### **Centers for Epidemiology and Animal Health (CEAH)**

The mission of CEAH, with a view to the future, is to explore and analyze animal health and related agricultural issues to facilitate informed decisionmaking in government and industry. CEAH also partners with the World Organization of Animal Health (OIE) and its member countries to improve international disease surveillance capabilities and analytic methods supporting trade decisions. CEAH has a multidisciplinary staff that includes agricultural economists, spatial analysts, GIS and computer specialists, veterinary epidemiologists, technical writers/editors, and data managers.

CEAH collaborates with university partners on analysis methods and tools. In some cases, the products produced are commercialized by the academic partners.

### **Center for Veterinary Biologics (CVB)**

The mission of the CVB is to implement the provisions of the Virus-Serum-Toxin Act (VST) to assure that pure, safe, potent and effective veterinary biologics are available for the diagnosis, prevention, and treatment of animal diseases. This mission mandates the use of sound scientific technology to:

- Ensure that biologics are free of disease-producing agents, especially foreign animal diseases
- Develop appropriate standards and procedures for product release
- Issue licenses and permits
- Monitor and inspect products and facilities
- Control field tests and release of veterinary biologics

CVB-developed methods and biological standards are applied equally to all products, but by the same token can be adopted whole by the regulated commercial manufacturers, becoming part of their manufacturing and release process.

### **2.5.3. Current Technology Transfer Goals, Objectives and Measures of Success**

APHIS-VS transfers technology primarily to State animal health agencies, animal owners, and their associations. Recent examples have included:

1. Information technology - Development of and training on Mobile Information Management systems for recording animal health information in the field for incorporation not only with VS supported data bases but other industry databases as well – utilized by industry and State/Federal animal health.
  
2. Animal disease surveillance - Development of and training in methodologies/software for outbreak surveillance (outbreak surveillance toolbox) – utilized by State/Federal animal health.
  
3. Geospatial analysis – Development of and training in a process to integrate spatial/geophysical features of the environment and county-level land use policies to determine suitable sites for carcass disposal– utilized by industry, State/Federal animal/public health.
  
4. Diagnostic assays – Training (courses and one-on-one) in diagnosis of high consequence diseases from foot-and-mouth disease to spring viremia of carp.
  
5. Diagnostic protocols and reagents – Protocols and reagents for assays and assay validation of Avian Influenza and Porcine Epidemic Diarrhea Viruses were provided to APHIS-equivalent laboratories in Mexico and the Dominican Republic.

### **3.0 Agricultural Research Service (ARS)**

<http://www.ars.usda.gov>

#### **3.1. Mission Statement**

ARS conducts research to develop and transfer solutions to agricultural problems of high national priority and provides information access and dissemination to:

- Ensure high-quality, safe food, and other agricultural products;
- Assess the nutritional needs of Americans;
- Sustain a competitive agricultural economy;
- Enhance U.S. natural resources and the environment; and
- Provide economic opportunities for rural citizens, communities, and society as a whole.

#### **3.2. Nature and Structure of Research Program**

ARS is the U.S. Department of Agriculture's (USDA) principal intramural scientific research agency. Agency goals are to find solutions to agricultural problems that affect Americans every day, from field to table, such as (a) protecting crops and livestock from pests and diseases, (b) improving the quality and safety of agricultural products, (c) determining the best nutrition for people from infancy to old age, (d) sustaining our soil and other natural resources, (e) ensuring profitability for farmers and processors, (f) keeping costs down for consumers, and (g) supporting the growth and development of rural America.

In fiscal year (FY) 2016, ARS employed approximately 1,675 scientists and 275 post docs, as well as, approximately 6,000 other employees to conduct 690 research projects at more than 90 locations. The

research projects were within 17 National Programs (Table 1). The Office of National Programs (ONP) in Beltsville, MD, plans the scope and objectives of agency’s research projects, while five Area Directors implement research projects at the locations in their geographic areas.

**Table 1. Research program management of ARS, showing 17 National Programs.**

<b>Animal Production and Protection</b>	<b>Natural Resources and Sustainable Agricultural Systems</b>	<b>Crop Production and Protection</b>	<b>Nutrition, Food Safety, and Quality</b>
Food Animal Production	Water Availability and Watershed Management	Plant Genetic Resources, Genomics and Genetic Improvement	Human Nutrition
Animal Health	Climate Change, Soils, and Emissions	Crop Production	Food Safety (animal and plant products)
Veterinary, Medical, and Urban Entomology	Pasture, Forage and Range Land Systems	Plant Diseases	Quality and Utilization of Agricultural Products
Aquaculture	Biorefining	Crop Protection and Quarantine	
	Agricultural and Industrial Byproduct		
	Agricultural System Competitiveness and Sustainability		

ARS conducts a series of reviews designed to ensure the relevance and quality of its research work and maintain the highest possible standards for its scientists. Customer input helps keep the research focused on the needs of the American food and agricultural system. Plans for each of the active research projects undergo a thorough, independent external prospective peer review managed by the Office of Scientific Quality Review (OSQR). All ARS employees, including the scientific workforce, are subject to annual performance reviews, and all research scientists and engineers have technology transfer as a performance element in their annual performance appraisal. Research scientists undergo a rigorous peer review Research Position Evaluation System (RPES) on a 3- to 5-year cycle. These processes ensure the continuing high-quality output of the ARS research addressing the needs of U.S. agriculture.

### 3.3. ARS Approach and Plans for Conducting Technology Transfer

Because of the delegations of authority by the Secretary of Agriculture, ARS' Office of Technology Transfer (OTT) is assigned the responsibility for obtaining patent protection for intellectual property (IP), developing strategic partnerships with outside organizations, licensing ARS technologies to the private sector and academia, and performing other activities that effectively transfer ARS research outcomes and technologies to the marketplace. USDA's Office of the General Counsel provides legal guidance to OTT in regard to intellectual property as needed.

The ARS technology transfer program has centralized policy and approval procedures that are managed by OTT. Research agreement negotiation and implementation is decentralized and managed by the ARS Area Offices. The Area Office Technology Transfer Staff serve as liaisons with scientists, ARS managers, OTT, university partners, and the private sector.

To facilitate technology transfer, OTT is organized into three sections. The *Administrative and Partnership Section* conducts day-to-day operations, coordinates technology transfer policy development, interacts with the Office of National Programs on agreement policy and review, and coordinates the activities between the partnership, patenting, and licensing sections. This Section maintains strong stakeholder relationships at the local, regional, and national levels, ensuring the adoption of research results. This Section is also responsible for coordinating and managing both agreements and the Agricultural Research Partnerships (ARP) Network. The *Patenting Section* provides strategic guidance to scientists regarding patent protection for their research results. The Section is also responsible for receiving invention reports, convening three National Patent Committees (Mechanical and Measurement, Life Sciences, and Chemistry), preparing and prosecuting patent applications, and

reviewing patent legal work performed by cooperator and ARS contract law firm. The *Licensing Section* manages invention licensing from all the intramural scientists in every USDA agency, including the review of license applications and the negotiation and monitoring of license agreements to assure compliance with agreement terms. This Section also collects and disburses license revenues, manages international patent filings, and provides expert advice on all matters related to USDA invention licensing.

Technology transfer is accomplished through many mechanisms, such as:

- Developing written information for customers and stakeholders, including scientific publications, publications in trade journals, and reports to stakeholders;
- Releasing plant germplasm to the public;
- Transferring research materials to scientists outside of ARS;
- Entering into formal partnership agreements, such as Cooperative Research and Development Agreements (CRADAs), and other cooperative agreements;
- Licensing IP (patents, Plant Variety Protections Certificates, and biological materials); and
- Participation in meetings with industry organizations and universities and workshops and field days; and distributing information to the public via the ARS Office of Communication, the National Agricultural Library, and other sources.

Because the ARS mission is to transfer technologies for broad public use by the most effective mechanism, ARS pursues patents and licensing principally 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. By ARS policy, patents are not filed on inventions that are considered to be only research tools. The purpose of this policy is to encourage scientific research. In licensing practices, ARS continues to reserve the right to allow use of any IP-protected technology for research purposes (non-commercial). Judicious use of intellectual property rights (IPR) is an important cornerstone of the patent committees. IPR is used as an incentive for commercialization and full realization of the research impact of USDA technologies.

Meaningful performance metrics in technology transfer are often difficult for research agencies to formulate. ARS is working to define better metrics for technology transfer within USDA. For example, successful outcomes for ARS may include improved agricultural practices, scientific information that enhances U.S. competitiveness, increased awareness about pathogens to help prevent human and animal diseases, or findings that help corporations and universities make informed decisions in allocating their research resources. Many of these outcomes do not require patenting or subsequent licensing for implementation. Additionally, ARS uses its ARP Network to match technical expertise of ARS researchers with firms who can capitalize on the ARS research capacities, facilities, and research outcomes.

Licensing policies also promote small business success with licensing fees in the early years, but with annual maintenance fees and royalties that escalate in subsequent years, sometimes after the first commercial sale of the product. Licensing further enhances commercialization by encouraging the broadest utilization of a Federal invention. ARS also incentivizes scientists on the reporting of

inventions, patenting, and licensing by providing 25 percent of the license revenues to inventors (this is a higher percentage than that required by statute, more than 15 percent). Thus, there are policies in place that incentivize commercialization, minimize transaction costs, and yet provide fair and equitable compensation for those who create Federal innovations. Development and expansion of the ARP Network further enhances the adoption of research outcomes.

These are all parts of a robust and effective technology transfer program that consists of a variety of mechanisms and programs to complement the research conducted by the agencies.

#### **3.4. Agricultural Research Partnerships (ARP) Network Program**

ARS founded the ARP Network to expand the impact of ARS research by enhancing the likelihood that these outcomes are adopted. Although replete with scientific expertise, the ARS research program does not have the resources or the authority to provide ARS commercial partners with business mentoring, marketing, manufacturing, and fiscal resources needed for the success of their businesses.

Consequently, the Network was established to provide these complementary assets. By combining ARS research expertise with complementary capabilities and talents of partnering organizations, the ARP Network stimulates economic growth through technological advancements. The ARP Network matches business needs with ARS innovations and research capabilities and provides business assistant services to help companies and startups solve agricultural problems, develop products, and create new jobs.

The ARP Network includes the important parties in an innovation ecosystem and has members spanning the United States with a shared vision to grow and sustain a competitive agricultural economy.

Members include ARS and stakeholders interested in agriculture-based economic development

including, but not limited to rural agribusiness; urban, community, and/or economic development groups; organizations that support farmers, growers, and/or food processors; and capital programs for business attraction and acceleration. Membership in the ARP Network is formalized through non-funded cooperative agreements. Currently, there are 33 ARP Network members in 28 States.

**FY 2016 accomplishments:**

- In FY 2015, OTT created a quarterly electronic newsletter called “ARP Notes” to update ARP members on ARS and members’ activities and events, and inform members of ARS partnerships and/or licensing opportunities. In FY 2016, ARP Notes distribution list consisted of 110 individuals that included ARP Network members, technology scouts, business development specialists, university faculty and staff, and other people involved in helping businesses and small companies commercialize technologies. Thirty-six ARS partnerships and/or licensing opportunities were advertised in ARP Notes.
- Held a Webinar with U.S. Small Business Administration (SBA) and the USDA National Institute of Food and Agriculture (NIFA) on the new Small Business Innovation Research (SBIR) Technology Transfer Program. This program encourages SBIR applicants to work with ARS researchers and/or license ARS technologies. The relevant language in the SBIR Request for Applications states: “Additional factors that will be considered in the review process include whether an application involves a CRADA with a USDA laboratory, or a license to a USDA technology.” In FY 2016, 11 CRADA projects were submitted for SBIR funding and 9 were awarded. Typically, 10-15 percent of USDA-SBIR proposals are funded. The higher success rate of CRADA-SBIR proposals (82 percent) is likely due to the ARS selection process in identifying partners and reviewing research

plans for solutions to agricultural problems of high national priority prior to submission to the SBIR program.

- Held a Webinar on “How to Partner with ARS to Move Technologies Out of the Lab and into the Marketplace.” This Webinar highlighted the four ARS Utilization Centers and the Beltsville Human Nutrition Research Center, which have unique facilities and equipment for research at pilot and near commercial scales.
- Actively participated in ARP member events in Ohio and Nebraska for presentations on how to partner with ARS to access ARS research capacities and technologies.

### **3.5. Technology Transfer Highlights**

- Forty-four new CRADAs were executed, and the scope of research was expanded through amending 64 active CRADAs. The current 156 active CRADAs are valued at \$87,653,676 over the course of their life (up to 5 years) with more than \$21,707,754 in funds going directly to ARS research projects. Approximately 45 percent of the active CRADAs are with small businesses. A new type of agreement called a Material Transfer Research Agreement (MTRA) was developed in FY 2013 to fit the needs of specific research projects (refer to President Initiative USDA 13). There are 321 active MTRAs, with 133 newly executed this year. (Refer to Table 1 in Section 3.7 and Figures 1 and 2 in Section 3.11.)

- Of the 44 newly executed CRADAs, 11 were with small businesses that applied for SBIR grants to further commercialize the CRADA research. Eight of these businesses were successful in obtaining a USDA-SBIR grant and one company successfully obtained a National Aeronautics Space Administration (NASA) SBIR grant. The typical success rate for SBIR applicants is 10-15 percent; ARS CRADA partners had a success rate of 82 percent. There could be several reasons for this higher success rate. For example, a company with a CRADA already had its project reviewed and approved by ARS prior to the SBIR review process. In addition, many of the CRADAs focused on an ARS technology that is known to have a commercial application.
- Two hundred and forty invention disclosures were received; 92 patent applications were filed; and 45 utility patents, 5 plant patents, and 3 PVPC certificates were obtained. There was 24-percent increase over the previous year in the number of invention disclosures (193 versus 240). Judicious use of intellectual property rights (IPR) is an important cornerstone of the patent committees. IPR is used as an incentive for commercialization and full realization of the research impact of USDA technologies. While the year in which a patent is issued is not typically the year in which the patent is filed, over time the ratio of patent applications filed over the number of patents issued represents a trend in the percentage of patents that are issued. (Refer to Table 2 in Section 3.7 and Figures 3 and 4 in Section 3.11.)
- Over the past 5 years, the rate of peer-reviewed publications per scientist appears quite stable at 2 to 2.5 per year. On the other hand, there appears to be an increasing trend in the number of collaborative research agreements and invention disclosures per scientist. (Refer to Figure 9 in Section 3.11.)

- Twenty-nine new licenses were executed, of which 31 percent were with small businesses and 48 percent with universities. The total number of income-bearing licenses has steadily increased over the last 5 years from 360 to 418. Sixty-nine percent of the income-bearing licenses were granted exclusively. The total earned royalty income (ERI) of \$3,633,329 was slightly higher than the previous year. Most of FY 2016's ERI came from a few licenses; the median ERI was \$3,966. (Refer to Tables 3, 4, and 5 in Section 3.7 and Figures 5, 6, and 7 in Section 3.11.)
- A template for a Commercial Evaluation License (CEL) was created. The CEL is a short-term, non-exclusive license to evaluate the commercial applications of the material and the licensed product and any inventions claimed in the licensed patent rights.
- To expedite and streamline the payment of license royalties, OTT established a pay.gov portal specific for royalty payments.
- In 2016, OTT established an Innovation Fund for ARS scientists to enable and expedite commercialization/adoption of their research outcomes. Projects are chosen based on their potential for advancing along the technology readiness continuum and moving closer to commercialization.
- Interagency agreements were renewed with the USDA Animal and Plant Health Inspection Service, the USDA Forest Service, and the U.S. Department of Interior, Bureau of Reclamation to provide technology transfer advice for invention disclosures, patenting, licensing, and research agreements.
- ARS laboratories won a Federal Laboratory Consortium (FLC) National Excellence in Technology Transfer Award and participated in a National Interagency Partnership Award. In addition, ARS

won a Regional Outstanding Technology Development Award, a Regional Outstanding Commercialization Success Award, seven Regional Excellence in Technology Transfer Awards, and a Regional State and Local Economic Development Award. (Refer to Section 3.10.)

- OTT worked with ONP to create a new Plant Breeding Handbook for the introduction of new plant germplasm and cultivars and restructured the Plant Protection Committee (PPC) that reviews plant releases for IP protection. Additionally, OTT held the first of several Webinars for ARS researchers to introduce the new policies and procedures for the release and protection of plant germplasm.
- OTT professional staff authored a paper describing the new ARS paradigm for technology transfer [Bahar, M. and R. Griesbach, 2016. A New Strategic Approach to Technology Transfer. Innovation Magazine 14 (3)]. In this new paradigm, technology transfer is an essential and integrated part of the research process beginning when the research objectives are first conceived. By aligning technology transfer with research objectives, the impact of research outcomes will be strengthened. More than 100 technology-transfer strategy sessions on this new paradigm were held with scientists, OTT staff, and Area Office technology transfer staff. In addition, OTT headquarters staff visited three field locations for training in FY 2016.
- OTT also sponsored the second I-Corps@ARS. In FY 2015, OTT successfully piloted a NSF I-Corps program specifically for ARS scientists and postdocs (I-Corps@ARS). I-Corps@ARS was a set of activities and programs that taught ARS researchers how to identify the real problems facing stakeholders and to develop valuable products and/or market opportunities that can emerge from their own research. In addition, I-Corps@ARS offered entrepreneurship training which helped the participants to be more innovative and impactful in their research programs. In FY 2016, the two

participants from the first I-Corps@ARS developed CRADAs to move their research in a new direction discovered during the I-Corp@ARS program.

- OTT professional staff played a very active role in the FLC both at the national and regional levels (e.g. Coordinator of the Mid-Atlantic region, member of the national executive board, trainers, tech transfer award reviewers, and meeting speakers).
- OTT represented the Department for the White House Office of Science and Technology Policy's Lab-to-Market, Maker Faire, and Intellectual Property Enforcement Committees. OTT participated in Inter-agency Working Group on Technology Transfer.

### **3.6. Response to Presidential Memorandum on Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Business**

In the USDA's implementation plan for the Presidential Memorandum, ARS described 13 initiatives to promote technology transfer and commercialization. These initiatives and their implementation are described below. The following initiatives were completed in FY 2013: USDA 1, USDA 8, USDA 9, and USDA 13; FY 2014: USDA 3; FY 2015: USDA 2, USDA 4, USDA 5, USDA 7, USDA 8, USDA 9, USDA 10, and USDA 12; and FY 2016: USDA 6 and USDA 11.

#### **USDA 1: New metrics proposed for standard annual reporting in addition to those required by Circular A-11 instructions on annual reporting of technology transfer**

This initiative was completed in FY 2013, and the new metrics are now a standard component of the ARS report.

**USDA 2: Update Policy and Procedure (P&P) 141.2 “Technology Transfer in ARS”**

This initiative was completed in FY 2015, and the new P&P was issued.

**USDA 3: Expand Agricultural Research Partnership (ARP) Network efforts to extend the impact of ARS research**

This initiative was completed in FY 2014, and the metrics are now a standard component of the ARS report.

**USDA 4: Expand outreach efforts in technology transfer to scientists in ARS**

This initiative was completed in FY 2015, and standard technology transfer PowerPoint training modules are posted on AgLearn for e-training.

**USDA 5: Encourage other S&T agencies to adopt OTT’s approach to technology transfer**

This initiative was completed in FY 2015, and the metrics are now a standard component of the ARS report.

**USDA 6: Explore expanded use of Enhanced Use Lease (EUL) authority as technology transfer tool to promote longer term relationships with key customer groups**

Under the 2008 Farm Bill, the Secretary was given the authority to establish a pilot project at the Beltsville Agricultural Research Center (BARC) to lease non-excess property to private or public entities. The EUL Project was used as a technology-transfer tool designed to provide longer term public-private partnerships than could be done through existing technology-transfer partnership instruments. The pilot authority was used to develop a process to identify underutilized laboratory resources that could be used by the private sector to commercialize ARS research outcomes.

Prospective lessees needed to establish either a licensing partnership or research collaboration with ARS. In exchange, EUL terms provide the lessee 20 years of use of the facility to develop its business. EUL authority proved to be a very successful strategy to leverage resources for entrepreneurial activities. USDA's first lessee (Plant Sensory Systems) was a small business that in FY 2013 was awarded a \$1.8 million ARPA-E grant (Better Biofuel Feedstock from Beets) based on the success of the research project conducted using BARC laboratory facilities. Access to these facilities was essential, because this small business did not have sufficient capital to build the facilities needed for this research project.

This pilot authority for BARC was reauthorized in 2014 Farm Bill. Discussions, which began in FY 2015, are ongoing to identify a partner to establish an accelerator on the BARC campus for agriculture businesses that utilize ARS technologies and/or research expertise.

**USDA 7: Beginning in FY 2012/2013, roll out a nationwide series of regional forums to identify issues and deliver solutions**

This initiative was completed in FY 2015, and the metrics are now a standard component of the ARS report.

**USDA 8: Provide opportunities for applicants to the USDA Small Business Innovation Research (SBIR) program to partner with ARS scientists to further develop science necessary for business success**

This initiative was completed in FY 2015. and the metrics are now a standard component of the ARS report.

**USDA 9: Provide Cooperative Research and Development Agreement (CRADA) partners opportunity to link to local Manufacturing Extension Partnership (MEP) resources to assist in commercialization efforts**

This initiative was completed in FY 2015, and the metrics are now a standard component of the ARS report.

**USDA 10: Work with regional incubators and economic development organizations to identify opportunities for ARS scientists and ARS commercial partners**

This initiative was completed in FY 2015, and the metrics are now a standard component of the ARS report on the ARP Network.

**USDA 11: Establishment of the “Branded Food Products Database for Public Health” Public-Private Partnership**

In FY 2013, ARS, the ATIP Foundation, and the International Life Science Institute North America established a public-private partnership to enhance the public’s health through increased knowledge of the nutritional content of the Nation’s food supply. This will be accomplished by obtaining comprehensive food composition data from the food industry and making it available to government, industry, the scientific community, and the general public through an enhanced USDA National Nutrient Database, developed and maintained by the ARS Nutrient Data Laboratory in Beltsville, MD.

In FY 2015, the public-private partnership successfully beta-tested a branded food products database. Five food manufacturers participated in a beta test by providing product label data and nutrition information on 245 products through a GS1-certified data pool provider, FSEnet. These data were passed to ARS for incorporation into the USDA National Nutrient Database.

In FY 2016, Secretary Tom Vilsack officially launched the USDA Branded Food Products Database, a free online resource for families, the food industry, and researchers containing nutrition details on more than 80,000 name brand prepared and packaged foods available at restaurants and grocery stores. The new database and user-friendly interface were the result of a partnership between ARS, International Life Science Institute North America, GS1 US, 1WorldSync, and Label Insight.

**USDA 12: Evaluate various options for reducing license negotiation transaction costs**

This initiative was completed in FY 2015, and the metrics are now a standard component of the ARS report.

**USDA 13: Develop Material Transfer Research Agreement (MTRA) as a new instrument to promote development and commercialization of materials from USDA**

This initiative was completed in FY 2013, and the metrics are now a standard component of the ARS report.

### 3.7. Metric Tables

**TABLE 1. Collaborative Relationships for Research and Development.**

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
<b>Total number active CRADAs</b>	243	230	214	211	156
Active traditional CRADAs	180	182	160	151	127
Active non-traditional CRADAs	63	48	54	60	29
Active CRADAs with small businesses	ND	116	96	98	70
<b>Number newly executed CRADAs, total</b>	53	62	43	59	44
Newly executed amendments <sup>1</sup>	82	86	72	76	64
Newly executed traditional CRADAs	39	41	29	44	32
Newly executed non-traditional CRADAs	14	21	14	15	12
Newly executed CRADAs with small businesses	20	21	10	31	12
<b>Total number active MTRAs<sup>2</sup></b>	12	100	188	212	321
Newly executed MTRAs	12	86	105	102	133
<b>Total number of active other agreements<sup>3</sup></b>	13,835	12,717	12,953	12,375	9,456
Newly executed other agreements	1,119	1,776	1,808	1,862	1,848
<b>Number newly executed MTAs</b>	970	991	906	743	823
Newly executed outgoing MTAs	661	647	506	513	539
<b>Total number of publications<sup>4</sup></b>	7,019	6,257	5,983	6,196	5,123
Peer-Reviewed Scientific manuscripts	4,769	4,409	4,367	4,395	3,851
Trade Journal manuscripts	57	73	68	55	59
Abstracts	2,193	1,775	1,548	1,746	1,213

\*ND- no data available.

1. Amendments extend existing Cooperative Research and Development Agreements (CRADAs) for additional years to a maximum of 5 years, change Statements of Work, and/or change funding levels.
2. Material Transfer Research Agreements. Involves collaborative research on a specific material.
3. Includes mostly Trust Fund Cooperative Agreements, Reimbursable Agreements, Non-Assistance Cooperative Agreements and Non-Funded Cooperative Agreements.
4. Number of published manuscripts.

**TABLE 2. Invention Disclosure and Patenting**

ND- no data available.

	FY 2012	FY 2013 <sup>4</sup>	FY 2014	FY 2015	FY 2016
<b>Total number new invention disclosures<sup>1</sup></b>	137	165	101	193 <sup>5</sup>	240 <sup>5</sup>
University co-owned	66	46	37	40	58
Non-University co-owned	ND	ND	ND	27	29
Based upon scientific discipline					
Biological Materials	ND	ND	ND	32	19
Life science	59	74	39	64	73
Chemical	53	49	32	48	48
Mechanical & measurement	14	19	9	18	21
Plant patents <sup>3</sup>	17	12	4	3	43
Plant variety protection <sup>3</sup>	ND	11	17	28	36
<b>Total number patent applications filed<sup>2</sup></b>	108	144	110	110	92
University co-owned	ND	36	34	25	10
Non-University co-owned	ND	ND	ND	26	9
Based upon scientific discipline					
Life science	ND	62	47	47	50
Chemical	ND	44	25	38	24
Mechanical & measurement	ND	13	17	15	10
Plant patents	ND	14	6	4	6
Plant variety protection	ND	11	6	6	2
<b>Total number patents issued<sup>2</sup></b>	60	60	78	84	53
University co-owned	ND	17	23	12	15
Non-University co-owned	ND	ND	ND	20	12
Based upon scientific discipline					
Life science	ND	17	36	33	23
Chemical	ND	25	21	20	13
Mechanical & measurement	ND	11	11	10	9
Plant patents	ND	7	10	15	5
Plant variety protection	ND	ND	ND	6	3

1. Inventions arising at the Federal lab. For FY 2013 and 2014 also includes the plants protected through Plant Variety Protection.
2. Includes U.S. patent applications, foreign patent applications filed on cases for which no U.S. application was filed, divisional applications, continuation-in-part applications, provisional applications, and Plant Variety Protection.
3. Plants may be protected in one of two ways based upon their mode of reproduction: patent (vegetatively reproduced) through the USPTO or variety protection (seed reproduced) through USDA Agricultural Marketing Service.
4. FY 2013 numbers were revised (higher) in FY 2014.
5. FY 2015 includes the addition of Biological Material Invention Disclosures.

**TABLE 3. Profile of Active Licenses**

\*ND- no data available.

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
<b>Total number active licenses</b>	363	380	392	404	419
Executed to small businesses <sup>1</sup>	118	137	150	147	150
Executed to startup businesses <sup>2</sup>	ND	11	12	12	6
Executed to universities	142	169	168	175	187
Amended in FY	ND	ND	10	5	4
<b>Invention licenses<sup>3</sup></b>	321	331	341	339	348
Executed to small businesses	ND	113	125	112	112
Executed to startup businesses	ND	11	12	12	6
Executed to universities	ND	162	160	166	178
<b>Other IP Licenses<sup>4</sup></b>	42	49	51	65	71
Executed to small business	ND	24	25	35	38
Executed to startup businesses	ND	0	0	0	0
Executed to universities	ND	7	8	9	9
<b>Total number newly executed licenses</b>	31	23	28	35	29
Executed to small businesses	15	9	15	16	9
Executed to startup businesses	ND	0	1	0	0
Executed to universities	12	10	10	9	14
<b>Invention licenses</b>		17	26	20	23
Executed to small businesses	ND	5	14	5	6
Executed to startup businesses	ND	0	1	0	0
Executed to universities	ND	10	10	8	14
<b>Other IP Licenses</b>		6	2	15	6
Executed to small businesses	ND	4	1	11	3
Executed to startup businesses	ND	0	0	0	0
Executed to universities	ND	0	0	1	0

1. A small business, together with its affiliates, must not have more than 500 employees.
2. For the purpose of this report, a startup company is a privately-held, U.S. for-profit company operating for less than 5 years and actively seeking financing to commercialize a Federal scientific work product.
3. Invention licenses refer to patents and plant variety protection certifications.
4. Other IP licenses refer to biological materials licenses.

**TABLE 4. Characteristics of Income Bearing Licenses**

	FY 2012	FY 2013 <sup>4</sup>	FY 2014	FY 2015	FY 2016
<b>Total number of income bearing licenses</b>	360	378	390	402	418
Exclusive	259	273	278	274	289
Partially exclusive	14	13	15	11	9
Non-exclusive	87	92	97	117	120
<b>Invention licenses<sup>1</sup></b>	318	329	339	337	347
Exclusive	252	265	269	266	280
Partially exclusive	14	13	15	11	9
Non-exclusive	52	51	55	60	58
<b>Other IP Licenses<sup>2</sup></b>	42	49	51	65	71
Exclusive	7	8	9	8	9
Partially exclusive	0	0	0	0	0
Non-exclusive	35	41	42	57	62
<b>Total number royalty bearing licenses</b>	128	134	131	139	145
Invention licenses	114	115	117	121	123
Other IP licenses	14	19	14	18	22

1. Invention licenses refer to patents and plant variety protection certifications.
2. Other IP licenses refer to biological materials licenses.

**TABLE 5. Income from Licensing**

\*ND- no data available.

	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
<b>Total income all active licenses</b>	\$3,806,164	\$4,385,952	\$4,927,938	\$5,066,988	\$4,784,466
Invention licenses <sup>1</sup>	\$3,670,692	\$4,053,931	\$4,733,200	\$4,842,256	\$4,456,054
Other IP licenses <sup>2</sup>	ND	\$332,021	\$194,738	\$224,732	\$328,412
<b>Total earned royalty income (ERI)</b>	\$3,059,989	\$3,353,876	\$3,610,774	\$3,509,904	\$3,633,239
Median ERI	\$5,000	\$3,609	\$3,232	\$3,525	\$3,966
Minimum ERI	\$44	\$5	\$32	\$13	\$5
Maximum ERI	\$757,219	\$856,987	\$575,753	\$728,017	\$818,537
ERI from top 1% of licenses	NP <sup>3</sup>				
ERI from top 5% of licenses	\$1,752,367	\$1,969,155	\$2,048,317	\$1,756,460	\$1,811,637
ERI from top 20% of licenses	\$2,604,008	\$2,892,796	\$3,103,143	\$2,856,924	\$3,043,395
<b>ERI distributed</b>					
Inventors	\$1,206,713	\$1,192,808	\$1,305,695	\$1,632,130	\$1,188,389
Funds to be used for salaries and tech transfer activities	ND	ND	\$2,812,269	\$2,819,906	\$2,051,317
Patent filing preparation, fees, & annuity payments paid <sup>4</sup>	ND	ND	\$809,974	\$621,701	\$393,533

1. Invention licenses refer to patents and plant variety protection certifications.

2. Other IP licenses refer to biological materials licenses.

3. Not presented, represents one license.

4. Approximately 40 percent is reimbursed when licensed.

**TABLE 6. Licensing Management: Elapsed Execution Time and Termination**

Agricultural Research Service (ARS)	FY 2012 <sup>1</sup>	FY 2013 <sup>2</sup>	FY 2014 <sup>3</sup>	FY 2015 <sup>4</sup>	FY 2016 <sup>5</sup>
<b>All licenses</b>					
- average (months)	5.8	3.5	5.9	2.8	4.9
- median (months)	4.2	2.3	5.8	2.5	3.7
- minimum (months)	0.3	0.4	0.9	0.5	0.9
- maximum (months)	19.7	12.5	21.5	10.0	16.0
<b>Licenses terminated for cause</b>	0	0	0	0	0

- <sup>1</sup> During FY 2012, USDA received 16 new invention license applications, for which 7 new licenses were granted, 9 license agreements are currently in negotiation, 0 applications were withdrawn by the applicants, and 0 applications are on hold by request of the applicant. The FY 2012 data is based upon 18 licenses granted to commercial licensees and does not include licenses executed with universities for co-owned inventions. In accordance with 35 USC 202(e), such licenses are granted for the purpose of consolidating rights in the invention, and therefore license applications are not required.
- <sup>2</sup> During FY 2013, USDA received 28 new invention license applications, for which 8 new licenses were granted, 15 license agreements are currently in negotiation, 3 applications were withdrawn by the applicants, and 2 applications are on hold by request of the applicant. The FY 2012 data is based upon 18 licenses granted to commercial licensees and does not include licenses executed with universities for co-owned inventions. In accordance with 35 USC 202(e), such licenses are granted for the purpose of consolidating rights in the invention, and therefore license applications are not required.
- <sup>3</sup> During FY 2014, USDA received 15 new invention license applications, for which 8 new licenses were granted, 5 license agreements are currently in negotiation, 2 applications were withdrawn by the applicants, and 0 applications are on hold by request of the applicant. The FY 2014 data is based upon 17 licenses granted to commercial licensees and does not include licenses executed with universities for co-owned inventions. In accordance with 35 USC 202(e), such licenses are granted for the purpose of consolidating rights in the invention, and therefore license applications are not required.
- <sup>4</sup> During FY 2015, USDA received 42 new invention license applications, for which 21 new licenses were granted, 18 license agreements are currently in negotiation, 2 applications were withdrawn by the applicants, and 1 application is on hold by request of the applicant. The FY 2015 data is based upon 26 licenses granted to commercial licensees and does not include licenses executed with universities for co-owned inventions. In accordance with 35 USC 202(e), such licenses are granted for the purpose of consolidating rights in the invention, and therefore license applications are not required.
- <sup>5</sup> During FY 2016, USDA received 26 new invention license applications, for which 6 new licenses were granted, 15 license agreements are currently in negotiation, 5 applications were withdrawn by the applicants, and 0 applications are on hold by request of the applicant. The FY 2016 data is based upon 14 licenses granted to commercial licensees and does not include licenses executed with universities for co-owned inventions. In accordance with 35 USC 202(e), such licenses are granted for the purpose of consolidating rights in the invention, and therefore license applications are not required.

### 3.8. Downstream Outcomes



### **NUTRITION, FOOD SAFETY, QUALITY**

#### **National Program:**

- **Human Nutrition, NP 107**
- **Food Safety, NP 108**
- **Quality and Utilization of Agricultural Products, NP 306**

#### **A database for branded food products.**

The National Nutrient Database, maintained by ARS in Beltsville, Maryland, contains information on the chemical composition of commonly consumed foods. However, although as many as 400,000 to 500,000 foods may be available in the U.S. food supply and the typical grocery store makes more than 30,000 items available to consumers, until recently the database contained information on fewer than 9,000 individual items. A public-private partnership among ARS, the North American branch of the International Life Sciences Institute, 1World Sync, and Label Insight brought nutritional label information of almost 90,000 additional foods to the database. This addition will strengthen the ability

of USDA and other Federal health agencies to more accurately monitor the food supply and to estimate nutrient consumption by consumers.

**The glycemic index is not reproducible enough for diet advice nor does it affect metabolism.**

Use of the glycemic index (GI) remains controversial. Although some health organizations and a few countries promote use of the GI for dietary recommendations, the USDA/HHS Dietary Guidelines for Americans do not promote it. Only limited data exist on variability between and within individuals and sources of that variability. ARS-supported researchers and Tufts University collaborators examined these factors in 63 healthy adult volunteers. Using white bread as the standard GI food, variation between people was 20 percent but within the same person, repeated measures varied 25 percent, which indicates too large a difference to be useful or reproducible. Blood measures of insulin and glucose status together explained almost one-third of that variability. Another study was conducted of 91 obese adults who ate reduced-calorie diets with either high or moderate total carbohydrate levels and high or low GI for 17 weeks. There was no effect of any diet on weight loss, fat loss, resting metabolic rate, or metabolic adaptation. These results demonstrate that GI is unlikely to be useful for guiding food choices in people.

**Long-term caloric restriction reduces inflammation without impairing immunity.**

Calorie restriction (CR) slows aging and cancer growth in many animal species, but its relevance to humans is unknown. Inflammation is now deemed a major contributor to chronic diseases, including heart disease and cancer. ARS-supported scientists in Boston, Massachusetts, collaborated with colleagues at several other institutions to directly study this question by assigning 143 healthy, non-obese adults to CR and 75 to continue their usual intake for 2 years. CR led to a 10-percent weight loss,

a reduction in circulating inflammatory markers, and both lower total white blood cell and lymphocyte counts. Long-term CR was associated with reductions in C-reactive protein and tumor necrosis factor-alpha by 40 percent and 50 percent, respectively; both of these markers are associated with increased heart disease, cancer, and other chronic health problems. CR had no effect on the immune response as measured by antibody response to vaccines and delayed-type hypersensitivity responses in the skin. Long-term CR appears to improve the health of young to middle-aged adults and may decrease risk of major chronic diseases.

**Naturally occurring trans fatty acids have adverse effects on serum lipids.**

It is generally accepted that industrially produced trans fatty acids (TFA) found in partially hydrogenated oils lower beneficial HDL cholesterol and raise harmful LDL cholesterol, but no studies had ever directly examined the effects of consuming naturally occurring TFA from ruminant animals. ARS scientists in Beltsville, Maryland, conducted a feeding trial in 106 healthy adult volunteers who ate either 3 percent industrial TFA, 3 percent ruminant TFA, or 1 percent conjugated linoleic acid (CLA, another naturally occurring TFA, but with a different chemical structure) for 24 days each. Both types of TFA raised LDL cholesterol levels in the volunteers, and ruminant TFA also raised HDL cholesterol levels, whereas CLA led to lower triglyceride levels and had no effect on other lipids. These results support the current labeling guidelines from the USDA Food Safety and Inspection Service and the Food and Drug Administration.

**Aging results in a decline of skeletal muscle quantity and function; major determinants of independent physical functioning in later life.**

ARS-funded researchers and Tufts University collaborators examined 3-year changes in muscle mass, strength, power, and physical performance among older adults and mobility-limited older subjects. They found that declining muscle function (strength and power) is an independent contributing factor, not just to falling, but to increased fear of falling and to deteriorations in quality of life. These findings reinforce the importance of preserving muscle health with advancing age to reduce fall risk and improve quality of life.

**Excess weight gain in pregnant women is driven primarily by greater calorie consumption.**

Excess weight gain during pregnancy leads to adverse outcomes for both mothers and infants. There has been ongoing debate whether excess gestational weight gain is the result of increased consumption or adaptive changes in energy expenditure during pregnancy. An analysis by ARS-supported scientists in Houston, Texas, and collaborators from Baylor College of Medicine, obtained measurements of these factors before conception and at three time points during pregnancy from 45 women. One-quarter of women gained excess weight and ate 750 calories more per day than those who gained ideal amounts of weight. All of the women exhibited decreased energy expenditure in physical activity during pregnancy but there was no difference by weight gain. Future interventions for weight gain during pregnancy may be more effective if focused solely on limiting energy intake while increasing the nutrient density of the diet.

**Baseline data for the 2020 Dietary Guidelines for Americans.**

One of the gaps in dietary recommendations is the lack of science for dietary advice aimed at children from birth to 24 months of age. The U.S. Government is committed to adding this age group to the dietary guidelines, so researchers from the ARS Children's Nutrition Research Center collaborated with investigators at Deakin University in Australia to analyze dietary intake reported by mothers for 2,740 infants and toddlers in a U.S. national survey from 2005 to 2012. In children younger than 1 year, infant formulas and baby foods were the leading source of calories and nutrients. In children aged 12 to 24 months, milk, 100 percent juice, and grain-based mixed dishes were important sources of calories and nutrients, but a number of foods contributing to energy intake had low nutritional quality, including sweet bakery products, sugar-sweetened beverages, and savory snacks. Non-flavored milk and ready-to-eat cereals were the most important contributors to micronutrient intakes. These data will help formulate future recommendations for this age group.

**A component of milk helps reduce the negative effects of higher saturated fat intake.**

The U.S. Dietary Guidelines urge limited intake of saturated fat because epidemiological data suggest it is associated with cardiovascular disease. However, results from previous human studies indicate this may not always be true. Consequently, ARS researchers at the Western Regional Research Center examined the effect of a high-saturated-fat meal on inflammatory markers in obese men and women for 6 hours following the meal. Two different forms of saturated fat (palm oil and whipping cream) were ingested with and without the addition of milk fat globule membrane (MFGM). MFGM surrounds the fat globules in milk and has been shown to reduce inflammation associated with some foods. ARS researchers found that consumption of MFGM with either palm oil or whipping cream resulted in lower

total cholesterol, LDL cholesterol, insulin, and small molecules associated with inflammation. This suggests that the addition of MFGM ameliorates the negative effect of a high-saturated-fat meal in overweight and obese men and women.

### **What We Eat in America.**

What We Eat in America (WWEIA) is the nutrition portion of the National Health and Nutrition Examination Survey (NHANES) conducted in partnership with the Centers for Disease Control and Prevention. In 2016, ARS scientists at the Beltsville Human Nutrition Research Center released food and nutrient consumption data for 2013–2014 in 56 publicly available tables. They also released the WWEIA Food Categories, which classifies more than 8,000 foods and beverages in the USDA food composition database into 152 categories. Thousands of scientific papers have been published over the years linking food consumption to nutrient status and health. NHANES is the only nationally representative survey of its kind and provides snapshots over time of the nutritional status of the American people.

### **Identification of structural components of dry beans that limit iron bioavailability.**

Dry beans are an important dietary source of many minerals, especially in areas where food is insecure. It may be possible to supply dietary iron through dry beans, but iron bioavailability is low in many varieties, and the reasons for low bioavailability are unclear. Approximately 80 percent of the iron in beans is found in a portion of the bean called the cotyledon, where cells are rich in protein and phytic acid. ARS researchers in Ithaca, New York, with their collaborators from Cornell University, found that cotyledon cell walls are not softened or rendered nutritionally useful by cooking and are highly resistant

to digestion in the upper intestine, which is the major site of iron absorption. This makes a major portion of bean iron unavailable for absorption until it reaches an area of the intestine where microbes can digest the cotyledon cell walls. However, the latter portions of the intestine do not have much capacity for iron absorption. Moreover, release of the iron is affected by distribution of iron in the seed or coat, and the presence of inhibitors of absorption, including dietary fiber and pigments, in the beans. These findings will help with development of bean breeding and processing strategies that can improve beans as a source of iron.

**Farmed salmon consumption reduces indicators of cardiovascular disease risk.**

It is known that salmon contains omega-3 fats considered to be heart healthy. ARS scientists in Grand Forks, North Dakota, studied the benefits of eating farmed salmon on lowering the risk of cardiovascular disease in healthy adults. Subjects ate increasing amounts of farmed salmon for 4 weeks, and indicators of cardiovascular disease risk were measured, including serum lipoprotein concentration, size, and density. The study results indicate that eating as little as 3 ounces of salmon twice a week modified serum lipoprotein particle size (a relatively newly developed risk factor for heart disease) and concentration in a manner associated with reduced cardiovascular disease risk.

**Intermittent feeding of the amino acid leucine enhances growth in newborns.**

About 9 percent of infants born in the United States are of low birth weight (LBW) or very low birth weight, and optimum nutrition is crucial for their immediate and long-term health. LBW infants are usually fed through a stomach tube either continuously or intermittently. ARS-funded scientists in Houston, Texas, with collaborators from Baylor College of Medicine, studied feeding regimens in young

pigs as a model for human infants. The piglets were fed an optimal formula diet continuously, or one supplemented with intermittent pulses of the amino acid leucine for 21 days. Addition of leucine to the diet enhanced lean growth by stimulating skeletal muscle synthesis. These results suggest that leucine may be useful in nutritional therapy to enhance growth in LBW infants and prevent later problems resulting from delayed development.

**Swine are a better model for human immunity than mice.**

Although the mouse is the most widely used laboratory animal model for human immunity, many discoveries from them do not translate to humans. ARS researchers at the Beltsville Human Nutrition Research Center compared part of the innate immune system (known as the inflammasome) in humans, mice, and pigs. Among 11 gene families that control the inflammasome, 9 were similar in humans and pigs but only 3 were similar in humans and mice. Confirming this observation, inflammatory cell responses in pigs were closer to those of humans than were cells from mice. This work supports using swine to model both human immunological and inflammatory responses to infection, as long as the noted differences are kept in mind.

**Validation of sampling the intestinal microbiome for metabolic activity.**

Bacteria in the large intestine have recently been discovered to have considerable influence on the body's metabolic activity, primarily through absorption of bacterially produced metabolites. To determine whether these metabolites are important, ARS researchers in Grand Forks, North Dakota, detected a total of 270 low-molecular-weight metabolites in contents of the colon and feces of mice. Of

that total, 93 percent were present in both specimens, establishing for the first time that fecal samples can be used as a valid, noninvasive proxy for most metabolic activity higher up in the intestinal tract.

**Cholesterol from the diet is not associated with increased risk for various cardiovascular diseases.**

Past nutritional advice urged consumers to reduce their intakes of food high in cholesterol because dietary cholesterol was thought to increase the risk for cardiovascular disease. ARS-funded researchers working with collaborators from Tufts University examined the effects of dietary cholesterol on cardiovascular disease risk factors in healthy adults by evaluating 40 published studies in a new systematic review and meta-analysis that covered 17 cohorts of 361,923 subjects, and 19 trials with 632 volunteers. They found that dietary cholesterol was not associated with a risk for various cardiovascular disease outcomes (i.e., death from ischemic heart disease and two types of stroke). Dietary cholesterol resulted in significantly higher blood levels of total cholesterol and LDL cholesterol, as well as blood levels of HDL cholesterol. But the studies reviewed were heterogeneous and lacked the methodologic rigor to draw any conclusions on the effects of dietary cholesterol and cardiovascular disease risk.

**A computer program for analyzing flavonoids in foods.**

Flavonoids are common plant compounds that may be beneficial to human health. A first step in determining whether flavonoids might have health effects is to identify the amounts and types of flavonoids in various plants. Scientists use a technique called liquid chromatography-mass spectrometry to analyze plants, however, this method yields thousands of potential, though unidentified, compounds. Results obtained by this method can take an expert weeks to analyze. ARS researchers in Beltsville, Maryland, developed an expert, first-of-its-kind, computer program, “FlavonQ,” to automate the

identification and measurement of three different classes of flavonoids (flavonols, flavones, and proanthocyanidins). The FlavonQ software has reduced the data analysis time for these complex analyses from weeks to hours. This expert system will allow rapid population of the USDA nutrient database with data for these flavonoids and facilitate investigation of their effects on human health.

### **Antimicrobial carryover and *Salmonella*.**

*Salmonella* can be transmitted to humans through the consumption of contaminated foods, including poultry. Contamination of raw poultry products occurs during live animal production and slaughter operations. The USDA Food Safety and Inspection Service (FSIS) monitors contamination of poultry through a testing program to protect consumers. ARS demonstrated that the current FSIS protocol for *Salmonella* testing of whole chicken carcasses may potentially lead to carry-over of intervention solutions, which are used to reduce pathogens in poultry processing, into the collection broth tested by FSIS inspectors. This carry-over could result in underestimating *Salmonella* levels in poultry processing operations. ARS scientists in Athens, Georgia, developed a modified collection broth capable of neutralizing a wide range of sanitizers, which resulted in a statistically more accurate reporting of *Salmonella* in poultry processing. FSIS subsequently validated and approved this new modified collection broth for regulatory sampling. In July 2016, FSIS field inspectors implemented the new protocol in their collection of samples for *Salmonella* testing.

### **Reevaluation of produce metrics.**

Current metrics used by the California Leafy Greens Marketing Agreements (LGMA) for leafy greens to ascertain the microbial safety of fresh produce required reevaluation. ARS scientists in Beltsville,

Maryland, examined the 60-day interval between flooding of fields and replanting of crops, and the 30-foot “no harvest” zone from the edge of the flood currently employed to prevent fecal contamination of crops. In intentionally flooded spinach fields with a negative 5 percent slope, *Escherichia coli* populations were found to decline more slowly in fall trials than in spring trials, and *E. coli* in soils and on spinach plants were detected 30 feet from the edge of the flood. These results suggest that LGMA metrics should be revised to include considerations of field and weather conditions that may promote bacterial movement and survival.

### **Imaging device for meat safety inspection.**

Current meat inspection in slaughter plants for food safety and quality attributes, including potential fecal contamination, is conducted through visual examination by human inspectors working under conditions that are poorly suited to conventional fluorescence detection methods that require ambient darkness. ARS researchers in Beltsville, Maryland, developed a handheld fluorescence-based imaging device (HFID) to highlight contaminated food and equipment surfaces on a display monitor during use under ambient lighting. This study assessed the effectiveness of the HFID to enhance visual detection of fecal contamination on red meat, fat, and bone surfaces of beef under varying ambient luminous intensities. Overall, diluted feces were detectable on the beef surfaces under all but the brightest ambient light intensities tested in the fluorescence images. This technology is patented and under license and commercial development by an industry partner and will support and improve meat safety inspection programs implemented by U.S. processors and regulatory inspectors.

### **Simultaneous drying and decontamination technology.**

The United States is the second leading producer and exporter of pistachios, providing 24 percent of the total world production at 257,000 tons, valued at \$1.6 billion in 2014. Pistachios previously have been recalled due to contamination with *Salmonella* and have caused outbreaks of salmonellosis, impacting public health and the pistachio industry. ARS researchers in Albany, California, have developed a novel technology based on sequential infrared heating and hot air that dries pistachios with an energy savings of 34 percent when compared to traditional hot air drying alone. The technology also creates a substantial reduction in population sizes of the *Salmonella* surrogate, *Enterococcus faecium*, on pistachio kernels and shells. This technology provides the tree nut industry with an efficient and effective approach to produce high-quality, safe pistachios and reduce the incidence of foodborne illness.

### **Extending the shelf life of fresh milk.**

Pasteurization has long been the standard method to extend the shelf-life of dairy products, as well as a means to reduce microbial load and the risk of food-borne pathogens. ARS-funded scientists at the Center for Food Safety Engineering (CFSE) at Purdue University in West Lafayette, Indiana, tested a novel pasteurization method in which milk is dispersed in the form of droplets and treated with low heat/pressure variation over a short treatment time. This low-temperature, short-time (LTST) method was very effective in reducing the level of microorganisms up to 100 million fold. The CFSE-developed BARDOT/BEAM technology was used to demonstrate that the only survivors of LTST were very few organisms (*Bacillus* species) that do not grow at refrigeration temperatures. The LTST process extended

the shelf life of the milk from a maximum of 35 days to approximately 63 days. The improved shelf life will positively impact the dairy industry in terms of shipping and overall sustainability.

### **Price tag of biological controls.**

The cost of interventions to improve the safety of food products is often unknown. ARS researchers in Wyndmoor, Pennsylvania, developed a formal cost model analysis for competitive exclusion microbes (CEM) for biocontrol of *Salmonella enterica* on tomatoes. The team found that the unit costs of CEM biocontrol range from 5 cents to 95 cents per kilogram of tomato for small-scale production and less than 1 cent per kilogram for large CEM production models. Since total variable costs for CEM were 95 percent of total production costs, the team determined that the use of CEM is best suited for large-scale application. However, the estimated total annual cost of CEM for control of *Salmonella enterica* on tomatoes is greater than sodium hypochlorite or gaseous chlorine dioxide. Therefore while CEM is an effective treatment process, other chemical treatment methods are more low cost. For high-value produce, CEM may complement existing technologies if efficacy and delivery systems can be optimized and its effects on gut microflora and associated factors are further evaluated.

### **Reducing contamination of poultry meat.**

*Campylobacter* contamination of poultry is responsible for hundreds of thousands cases of bacterial-associated foodborne illness. ARS scientists in Athens, Georgia, optimized a novel in-package ozonation technology to reduce *Campylobacter* species contamination on chicken breast filets. The scientists noted significant reductions of natural bacterial flora and surface-applied bacterial pathogens (*Campylobacter jejuni*) when using this technology. Currently, this technology is being expanded to

include major food quality (*Pseudomonas fluorescens*) and additional food safety (*Salmonella* spp.) microorganisms. This novel technology will provide commercial processors a method to significantly reduce bacterial pathogens and other bacterial flora on packaged breast filets and increase the quality and safety of the final product as it leaves the processing plant.

### **Chickens resistant to pathogens.**

Breeding chickens resistant to *Salmonella* and *Campylobacter* infection is considered, along with vaccination, to be a potential long-term intervention in controlling bacteria in broiler chicken production. New approaches are needed to produce live poultry that are not colonized by these harmful bacteria, which would translate into pathogen-free meat products for human consumption. ARS researchers in College Station, Texas, have identified a population of roosters from the Athens Canadian Random Bred lineage, a 1950s meat-type chicken, with differential expression of key immune markers to serve as sires for the generation of a F1 population of chickens selected for a more efficient innate immune responsiveness. ARS is attempting to breed chickens with natural resistance to *Salmonella* and *Campylobacter* by using older original chicken populations with greater genetic diversity to produce more pathogen-resistant broilers. Development of microbial pathogen-resistant birds would be a dramatic success in enhancing the microbial safety of poultry meat products reaching the consumer.

### **Detection of pesticides and environmental contaminants.**

Improved analytical methods are needed to better monitor pesticides and persistent organic pollutants in meat and poultry. ARS researchers in Wyndmoor, Pennsylvania, have developed and validated an easy and reliable high-throughput analysis method for 192 diverse pesticides and 51 environmental

contaminants in cattle, swine, and poultry muscle. With samples prepared based on the ARS-developed QuEChERS approach, the validated method was successfully applied to the analysis of known contaminated meat samples that demonstrated the utility of the method for implementation in regulatory and commercial laboratories. The method was transferred to the USDA Food Safety and Inspection Service for future validation and implementation in routine regulatory monitoring of contaminants in meats.

### **Egg candling lights for official grading.**

Poultry farmers and regulatory agencies use candling, where a bright light source is used to show details within the egg shell, to learn which eggs are fertile and which will hatch into chicks, and for maintaining quality assurance purposes. Official graders with the USDA Agricultural Marketing Service (AMS) needed a new system for candling eggs. ARS scientists from Athens, Georgia, designed and developed prototypes of a high-intensity light emitting diode (LED) white light for candling eggs. Both a portable battery-powered model and a stationary model were created. A material transfer agreement was used to complete the design and to transfer the technology to a U.S. commercial partner. The company has now completed the second prototype revision and started selling the lights to the public. AMS has plans to purchase several hundred of these lights to replace all of their existing obsolete candling lights.

### **Detecting food adulterants.**

Food adulteration is a critical and serious international issue and is usually considered an act whereby food is intentionally contaminated to reduce its safety and quality. Intentional contamination of milk-based infant formulae with melamine in recent years has resulted in numerous illnesses and deaths and

in a large recall of product. ARS researchers in Beltsville, Maryland, developed a line-scan Raman chemical imaging system to detect adulterants in milk powder. With the limits of detection for both melamine and urea estimated at an order of 50 parts per million, this imaging system can be used for rapid, nondestructive, and quantitative measurement of melamine and other chemical adulterants that can pose risk of illness and even death when present in dry powdered food ingredients. This technology is under patent review and has been made available to commercial partners for continuous evaluation of milk powder, especially for the production of infant formulae.

#### **Food containers with antimicrobial surface.**

Containers are used for fruits and vegetables in the field and storage, on display in stores, and during transportation; however, they can be easily contaminated with foodborne pathogens. When a contaminated container is in contact with food, pathogens transfer from the container to the food, hence, the importance of having a pathogen-free container. ARS researchers in Wyndmoor, Pennsylvania, developed methods and coating formulas to produce food containers with an antimicrobial surface. Specifically, the scientists used titanium dioxide (TiO<sub>2</sub>) nanopowders, which are ingredients in food coloring, with polymers to form an antimicrobial coating on the container surface. The surface coatings were activated by visible light to inactivate *E. coli* O157:H7 on the container surface, and in tests reduced the pathogen by 99.7 percent. The research further demonstrated that the developed methods and coating formula could be applied to different types of containers made of metal, wood, plastics, or paperboard, and for various foods, especially for fruits and vegetables. An invention disclosure and patent for the technology has been submitted to facilitate licensing by industry.

### **Detection using bacteriophage.**

Rapid detection of the foodborne pathogen *Escherichia coli* O157:H7 is of vital importance for public health worldwide. ARS-funded scientists at the Center for Food Safety Engineering at Purdue University in West Lafayette, Indiana, have modified a bacteriophage (bacterial virus) specific for *E. coli* O157:H7 by adding a gene from a bioluminescent shrimp that causes the live cells of the pathogenic *E. coli* to glow after bacteriophage infection. This diagnostic tool is very specific and very sensitive, detecting as little as five cells of the pathogen in less than 7 hours after culture enrichment. The method also has potential for direct detection of higher pathogen concentrations directly in ground beef. The process uses very low concentrations of bacteriophage and can be integrated into current laboratory protocols. The coupling of low bacteriophage concentrations and the ease of integration into current protocols provide a low-cost method for the detection of *E. coli* O157:H7 with the potential to improve pathogen surveillance and provide for a safer food supply. The technology was patented and licensed to a startup company based in Indiana that, based on the potential of this technology, was awarded State funding for capitalization and initial startup costs to assist in its commercial development.

### **Alternative to animal bioassays for toxins.**

Food poisoning caused by staphylococcal enterotoxins is among the leading causes of food-borne outbreaks. The current method for detection of enterotoxins activity is an in vivo monkey or kitten bioassay. However, this expensive procedure has low sensitivity and poor reproducibility, requires many animals, and is impractical to test a large number of samples. ARS researchers in Albany, California, developed a robust cell-based assay that produces a measurable bioluminescence when

exposed to active staphylococcal enterotoxin type E concentrations. The assay is 106 times more sensitive than a typical ELISA assay and 109 times more sensitive than the monkey and kitten bioassay. Development of this assay into commercial use could make it an economical and effective alternative to current detection standards using animal models. This is a new technology currently under patent application.

### **Inorganic arsenic in rice.**

Arsenic is a naturally occurring heavy metal found in both soil and water and is the primary source of the inorganic arsenic found in rice. Some research has suggested that consumption of arsenic through rice-based products has toxic effects, including limiting cognitive and immune system development in children, potential premature births, and cancer due to long-term chronic exposure. The FDA developed a method to measure inorganic arsenic in rice that costs about \$200 per sample. Because the World Health Organization through Codex and the U.S. Food and Drug Administration (FDA) have set limits for the amount of inorganic arsenic that can be present in rice, simpler and much less costly methods for analysis are needed. ARS scientists in Beltsville, Maryland, developed a new method and cross validated it with the FDA method, showing comparable results from a series of diverse rice types and samples. The new method costs less than \$40 a sample, an 80-percent reduction from the FDA method. This new method will benefit rice growers, the rice industry, infant cereal manufacturers, and consumer organizations that monitor rice-based products. The method is currently undergoing validation by the Association of Official Analytical Chemists prior to implementation.

### **Detection of violative residues.**

Because there is serious concern regarding antibiotic residues in food products, meat, poultry, and egg products are tested through the U.S. National Residue Program for the presence of more than 100 compounds. Sampling of meat products is done at the processing plant, and “swab tests” are used to quickly determine initial negative or positive results. Samples are typically taken from consumable organ meats such as liver or kidney where most compounds accumulate in the highest quantities. Penicillin G is a valuable antibiotic for the treatment of infection in female pigs (sows), however, penicillin G residues deplete very slowly from some sows, and more rapidly in others. As a result, the marketing of groups of sows treated with penicillin G must be managed based on animals that metabolize penicillin G the slowest. ARS researchers in Fargo, North Dakota, demonstrated that an inexpensive test strip could rapidly detect penicillin residues in the urine of commercial sows, and that the presence of penicillin in urine accurately predicts violative penicillin residues in edible meat and organ tissues. The use of an inexpensive and easy-to-use test strip will allow the differential marketing of penicillin-free sows and sows retaining drug residues. The technology has been transferred to the USDA Food Safety and Inspection Service for routine implementation and use in the National Residue Program.

### **Antimicrobial resistance.**

The impact of potential antimicrobial resistant bacteria in livestock waste runoff has been a growing topic of public concern. ARS scientists in Clay Center, Nebraska, compared the populations of antimicrobial-resistant bacteria and the presence of antimicrobial resistance genes within samples of

livestock and municipal waste streams discharged from municipal wastewater treatment facilities, cattle feedlot runoff catchment ponds, swine waste lagoons, and environments considered low impact (a municipal lake and a prairie). The results showed that the prevalence and concentrations of antimicrobial-resistant bacteria were similar among the livestock and municipal sample sources, but there were differences among the antimicrobial resistance genes found in agricultural, environmental, and municipal samples, with municipal samples harboring the highest number of antimicrobial resistance genes. It was concluded that antimicrobial resistance is a very widespread phenomenon where antimicrobial resistance can be found in cattle, swine, and human waste streams, though a higher diversity of antimicrobial resistance can be found in human waste streams. This study indicates that antimicrobial resistance bacteria are widespread, and that humans are a reservoir of antimicrobial resistant bacteria for other humans. This was previously unknown and indicates that agricultural systems are not the only source of antimicrobial resistance.

***Escherichia coli* in culled dairy cows.**

Enterohemorrhagic *E. coli* (EHEC), also known as STEC (Shiga-toxin producing *E. coli*), are the cause of serious foodborne illness, chronic sequelae, and deaths in the United States. The most well-known of these types of bacteria is *E. coli* O157:H7, but six additional pathogenic *E. coli* strains are of concern to regulatory agencies, including the USDA Food Safety and Inspection Service, and cause severe disease in humans. EHEC can be found in most groups of cattle, but it is not known whether any are specific to culled dairy cows harvested for beef. ARS scientists from Clay Center Nebraska, and Wyndmoor, Pennsylvania, and colleagues belonging to the STEC-CAP research group (a consortium project funded through the USDA National Institute of Food and Agriculture) examined matched fecal, hide, and pre-intervention carcass samples collected from culled dairy cows at harvest. Culture isolation found EHEC

in 6.5 percent of feces samples, 15.6 percent of hide samples, and 1 percent of carcass samples. It was concluded that EHEC are common on the hides of culled dairy cattle, and that feces are an important source of EHEC contamination of hides. This information is critically important for the epidemiologist, regulatory monitoring of animals, and development of both pre- and post-harvest interventions. This information has been transferred to the cattle industry through various industry partners, including the North American Meat Institute, National Beef Association, American Beef Association, and the USDA Food Safety Inspection Service.

### **Poultry litter management.**

The poultry and animal industries continue to combat the spread of foodborne pathogens in food products and have spent millions of dollars attempting to control *Salmonella* and *Campylobacter* with minimal results. Until recently, the focus has largely been on implementing management strategies for reducing the movement of bacteria from the poultry house environment. Because of increasing cost of new bedding materials, modern broiler producers utilize the same litter for growing out multiple flocks. ARS researchers in College Station, Texas, assessed the changes in bacteria and dispersion of several litter practices in a commercial broiler house. The results demonstrate that better clean-out practices have the potential to reduce contaminant buildup of many chemical pollutants in the litter within the broiler production facility, such as nitrates and heavy metals, including iron, manganese, and zinc. The research also established that proper disposal of litter is necessary for environmental health. This study provides an understanding for poultry producers of the role in food safety, as well as animal health, of litter management approaches and their impact on the environment. This is a critical issue for producers since contaminated flocks are subject to closer inspection by USDA regulatory agencies

**Antibiotic determinants.**

Cattle are frequently administered macrolide antibiotics such as Azithromycin and Erythromycin for the prevention or treatment of various diseases. To examine the effect of macrolide exposure on fecal shedding of resistant bacteria, rapid methods for characterizing resistance gene content were needed. To address this need, ARS researchers in Clay Center, Nebraska, developed a method to detect seven major antibiotic resistance mechanisms simultaneously. This method was successfully used to screen more than 2,000 bacterial isolates, which revealed subpopulations of bacteria containing antibiotic resistance genes not previously recognized in these organisms. This information will be useful for epidemiologists and scientists concerned with the lateral transfer of antibiotic resistance genes between pathogenic and commensal bacteria and the subsequent development of resistance.

**New tomato variety developed from fruit taste study.**

Many years of breeding tomatoes for disease resistance, yield, and size has resulted in fruit that lack flavor. In a collaborative study involving ARS scientists in Fort Pierce, Florida, and the University of Florida tomato breeding program, the researchers evaluated 38 tomato varieties over 7 years to understand tomato flavor. Tomato variety and harvest season significantly influenced sensory perception and chemical profiles. Based on this study, University of Florida collaborators developed a new variety, 'Tasti-Lee', which is now readily available in supermarkets. When comparing the industry standard, 'Florida 47', with 'Tasti-Lee' for the 29 compounds that affect tomato aroma, 8 were higher in 'Tasti-Lee' compounds (which contributed to ripe-fruit and floral aromas), whereas 4 were higher in 'Florida 47' compounds (which contributed to

non-ripe green fruit aromas). This chemical model for tomato flavor quality is available to breeders seeking to improve fruit and vegetable flavor.

**New tools for apple producers to avoid superficial scald.**

Apple fruit superficial scald results from chilling stress during the first month after harvest and results in dark, sunken peel tissue after 3–6 months of cold storage. Low-oxygen controlled atmosphere storage can control superficial scald, but is not always effective across apples from different orchard lots and production seasons. ARS scientists in Wenatchee, Washington, have identified natural early warning compounds that accumulate in the peel of harvested apples before scald appears regardless of the prior growing conditions. When these early warning compounds occur, storage-room oxygen levels can be reduced or fruit can be marketed before symptom development. This practice provides apple producers with methods to avoid superficial scald throughout the postharvest supply chain.

**Potato cultivars with reduced acrylamide content identified.**

Acrylamide is an unwanted and potentially toxic by-product produced when carbohydrate-rich foods, such as French fries, are processed at high temperatures. ARS researchers in Fargo, North Dakota, evaluated 56 advanced potato clones grown in Idaho, Maine, North Dakota, and Wisconsin for process quality, asparagine content, and acrylamide levels using standardized storage, processing, and evaluation procedures. Several clones exhibiting excellent processing characteristics and very low acrylamide levels were identified. These clones are being evaluated in more detailed trials to identify candidates to replace currently used varieties in the commercial production of processed potato products.

**Near-infrared spectroscopy used to measure gluten content in cereals.**

The U.S. Food and Drug Administration (FDA) and the Commission of European Communities require that gluten-free oats or products can be labeled as non-gluten only if they contain less than 20 parts per million gluten, the established safe consumption limit for people with celiac disease. The need for testing samples for gluten products is highly sought by industry to assure that a gluten-free product can be delivered. In response to this need, a near-infrared instrument developed by ARS scientists in Manhattan, Kansas, was compared with a commercial near-infrared instrument to classify grain types on a single grain basis. Both instruments could distinguish oats and groat kernels from other grains with 95 to 100 percent accuracy. The in-house instrument had better accuracy, although it was a magnitude slower than the current commercial instrument. This instrument, which is being tested by the FDA, provides an excellent method for evaluating commercial samples of gluten-containing products.

**Plant sugars converted to antimicrobial compounds.**

The yeast *Aureobasidium pullulans* is able to convert agricultural sugars to compounds called liamocins, which are selective antibacterial agents for controlling problematic bacteria in veterinary and clinical medicine. Liamocins are unique in that they have varying degrees of antimicrobial activity. ARS scientists in Peoria, Illinois, developed genetic methods to control the type of liamocin based on the sugar used to grow liamocin strains. This technology allows production of specific liamocin strains that attack specific bacterial organisms, which benefits veterinary care by offering non-antibiotic treatment options.

### **Vegetable oils made into bio-plastic.**

Replacing petroleum oils with plant oils in the production of usable by-products, such as plastics, is complicated. One problem with plant oils is that they contain more oxygen atoms than necessary to make by-products. These oxygen atoms must be removed to control reactions necessary for the plastic to be strong, durable, and useful. ARS scientists in Peoria, Illinois, developed a new technology that uses a very small amount of catalyst to remove excess oxygen with the only coproduct being carbon dioxide, which is captured. A patent application covering this technology has been filed. The use of this technology would enable major industrial polymer partners to substitute petroleum oil for vegetable oil in making plastic products.

### **Sesamol, an alternative to synthetic antioxidants for protection of omega-3 oils.**

The use of omega-3 oil supplements and foods fortified with these oils has increased in recent years because omega-3 oils have beneficial health effects, such as reducing the incidence of heart attacks and inflammation, and in fetal brain development. However, omega-3 oils are easily catabolized by oxidation and heat, requiring antioxidants to protect them from degradation. ARS researchers in Peoria, Illinois, treated fish oil with sesamol, a natural compound found in sesame seed oil, to prevent oxidation in an accelerated storage study in which the fish oils were subjected to heat and oxygen. Sesamol demonstrated stronger antioxidant activity than the current and widely used, commercial synthetic antioxidant, butylated hydroxytoluene (BHT), and the leading commercial natural antioxidant, rosemary extract. Sesamol offers an inexpensive, food label-friendly alternative to synthetic antioxidants for protection of omega-3 oils, and offers advantages over rosemary extracts, which contribute flavor, odor,

color, and solubility issues associated with the resulting oil products. Industry has expressed an interest in scaling up production for commercial distribution.

**Near infrared-based detection of pits in cherries.**

High-speed sorting of cherries to remove pits that were missed by the mechanical pitting machine is a high-priority research area for the cherry industry. ARS researchers in Albany, California, used near-infrared spectroscopy to identify pits in cherries with an accuracy greater than 99 percent. This optical sorting device, based on reflection of light from a limited set of wavelengths and at high speed, has been adopted by the U.S. cherry processing industry and can detect pits remaining in cherries after mechanical depitting, thus reducing the potential for injury to consumers and subsequent litigation.

**Bio-based sponges derived from tannery waste.**

Due to fierce global competition, the American leather and hide industries need to produce novel products from raw hides and recycled tannery waste to stay competitive. ARS researchers in Wyndmoor, Pennsylvania, recently developed novel collagen sponges from hides and tannery waste that have many unique properties desirable in medical applications. The sponges are widely used to stop bleeding in surgery and as “scaffold” material in tissue regeneration. Collagen sponges can be generated from untanned hides, limed hides, and delimed-bated hides, as well as tannery waste of limed splits and their trimmings. This research is instrumental in helping the U.S. hides and leather industries diversify by producing bio-based sponges, which have many high-value medical applications. A cooperative agreement is being established with an industry partner to commercialize this technology.

**Accurate and rapid methods for assessing grain soundness.**

The volatile organic compounds (VOCs) in soft winter wheat are responsible for odor and extrinsic factors, such as fungal infestation and postharvest weathering, and as an indicator of overall grain soundness. ARS scientists in Wooster, Ohio, profiled major VOCs in eastern soft wheats, and identified five compounds (four alcohols and one aldehyde) that had variable profiles relating to grain maturation, fungal infection levels, and spoilage organisms. The scientists developed these VOC profiles of wheat grains into a rapid and accurate method that is being used by storage elevator operators, millers, and USDA Agricultural Marketing Service grain inspectors for assessing grain soundness, fungal infection levels, and postharvest spoilage.

**Improved water-resistant, sustainable, bio-based glue formulations.**

Improved water resistance in building materials, such as plywood, is of particular interest to manufacturers because most protein-based glues currently in use exhibit poor water resistance. ARS scientists in New Orleans, Louisiana, have discovered that including additives in cottonseed-based protein glues improves adhesive performance. Both adhesive strength and water resistance are improved by additions of small amounts of organic acids or phosphorous-containing compounds derived from cotton processing waste materials. This water-resistant glue is being used in the development of a new “green” building material made from commercial timber harvesting trimmings and waste in collaboration with ARS and Mississippi State University scientists.

**New, rapid, and accurate cotton moisture measurement by microwave.**

Moisture content of cotton fiber is an important fiber property, but it is currently measured via a laborious, time-consuming, oven-drying method that has many performance issues. ARS scientists in New Orleans, Louisiana, developed a moisture meter using a microwave that performs rapid, precise, and accurate fiber moisture measurements. This microwave instrument, compared to two current oven-drying reference methods, had better precision of moisture measurements with near 99 percent accuracy. Also, the effect of the measurement method on the cotton fiber weight was minor, and long-term stability was excellent. The microwave moisture method is viable and applicable for daily quality control use. An extensive, multi-month, on-site trial of the instrument was performed by the USDA Agricultural Marketing Service with favorable results. In addition, an international technology company is investigating potential food applications.

**A potent, bio-based herbicide from toothpick weed.**

Plants can be a rich source of novel and structurally diverse compounds that are effective and environmentally safe herbicides. ARS scientists in Oxford, Mississippi, selected toothpick weed (*Ammi visnaga*) for further study after screening nearly 2,400 plant extracts. Phytotoxicity-guided fractionation of the extracts from the toothpick weed yielded two compounds, khellin and visnagin, whose herbicidal activity was not previously known. Khellin and visnagin inhibited the growth of lettuce and duckweed; also, both compounds reduced growth and germination of the weeds ryegrass, morning glory, foxtail, and millet. The inhibitory activities of these compounds are similar to those of the commercial herbicides acetochlor and glyphosate. These results support the potential of visnagin and khellin as

bioherbicides or as lead molecules for the development of new bio-based herbicides. Commercial manufacturers of herbicides are be apprised of this technology.

**Sensing food contamination by hyperspectral imaging.**

Commercial analytical laboratories traditionally rely on highly complex instrumental/chemical methods for detecting contaminant levels; however, these methods are affected by operator skill and analysis time that make them ill-suited for industrial food processing facilities. Near-infrared hyperspectral imaging is a simpler technique that uses light wavelengths just beyond the visible light region to analyze food products. ARS scientists in Beltsville, Maryland, developed a nondestructive spectral imaging method to examine sources of contamination in food, such as mold in cereal grains or by deliberate adulteration (e.g., melamine in milk powder). This work benefits manufacturers of food powders by offering a method that is readily adaptable to industrial processing operations. Commercial adopters of this technology are being sought.

**Modification of hemoglobin improves its water clarification properties.**

Hemoglobin can be used as a bio-based substitute for certain water treatment chemicals. The performance of hemoglobin in this application is very good in clarifying water, but the water to be treated must be slightly acidic for highest efficiency. ARS researchers in Wyndmoor, Pennsylvania, modified hemoglobin waste from the U.S. poultry processing industry through a simple chemical reaction that attaches alcohol molecules to specific sites on hemoglobin. The modified hemoglobin was much more potent in water clarification and had a significantly reduced need for acidity. The modified hemoglobin produced in this research is substantially more attractive as a bio-based water treatment

chemical compared with unmodified hemoglobin. This bio-based water filtration material is being tested by ARS water research scientists.



## **ANIMAL PRODUCTION AND PROTECTION**

### **National Programs:**

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

**Understanding the genetics of a glycoprotein and its potential as a vaccine candidate for classical swine fever.**

A DNA codon is a series of three nucleotides that maintain the codes for specific amino acids, which are the building blocks of proteins. Some amino acids have more than one codon, and some codons are used more often than others. This tendency to use a particular codon can vary between microorganisms and their animal hosts. ARS scientists in Orient Point, New York, determined that the E2 glycoprotein, a determinant of virulence of classical swine fever virus (CSFV), had a similar codon usage bias as pigs,

its natural host. They explored the effect of switching the native codons in E2 for less frequently used codons. Their studies showed that the genetically altered CSFV no longer caused disease. Although this phenomenon is still a subject of investigation, it is thought to occur because a changing codon affects the ability of a gene to be expressed. Interestingly, when ARS scientists explored the potential use of this phenomenon to generate a vaccine strain, they found that the altered virus was able to protect animals against the disease. By using synonymous codons and not changing a single amino acid, this potential vaccine leaves all natural antigenic epitopes intact. The benefits of producing vaccines using these genetic alterations is that the antigenic profile of the virus remains intact, which is important for inducing a protective immune response. Additionally, by changing the nucleotide composition, genetic markers are now available that could be used to differentiate between vaccinated and infected animals.

**A better understanding of the mechanisms and pathogenesis of foot-and-mouth disease in cattle.**

Foot-and-mouth disease virus (FMDV) is the most infectious disease of animals and affects food security in much of the world. Unfortunately, a key challenge in the control of FMDV is that 50 percent of vaccinated cattle become persistently infected. Persistent FMDV infection in cattle is largely responsible for the massive depopulation of animals because of the fear these animals, although asymptomatic with no clinical signs, may spread FMDV and infect other animals. Very little is known about the mechanisms that lead to this reinfection. ARS scientists in Orient Point, NY, found that the divergence between carrier animals and FMDV-free animals occurs as early as 10 days after infection. Microscopic localization of the virus indicated persistent infection of specific regions of the nasopharyngeal mucosa. These findings provide new insights into paths that may be taken to develop vaccines that could prevent animals from serving as carriers of FMDV to unvaccinated

animals. Having a vaccine to prevent FMD-persistent infections would support the implementation of a "vaccine to live" strategy and eliminate the needless slaughter of vaccinated animals.

**A better understanding of classical versus atypical bovine spongiform encephalopathy.**

In 2006, a case of atypical bovine spongiform encephalopathy (BSE-H) was diagnosed in a cow with a heritable genetic mutation in the bovine prion protein gene (PRNP). Unlike classical BSE, which is caused in cattle that eat contaminated BSE material, it is thought that atypical BSE cases may occur spontaneously in cattle due to genetic mutations in the PRNP. ARS scientists in Ames, IA, conducted a series of pathogenicity studies and showed that the survival time of the cattle with the genetic mutation and inoculated with BSE-H was shorter (10 months) than cattle without the mutation (18 months). This genetic effect was not observed when cattle with or without the genetic mutation were inoculated with classical BSE. Their survival time was 26 months, regardless of whether or not the cattle carried the genetic mutation. The results of these studies demonstrate that the genetic mutation associated with atypical BSE exhibits a number of features that differ from classical BSE. Understanding the association between this genetic mutation and BSE provides important information on the potential public health risk of atypical BSE.

**A better understanding of Marek's disease.**

Marek's disease (MD) is a Herpes virus infection in chickens, and highly virulent strains continue to be a problem on poultry farms. Recent interest in the role of the microbiome (i.e., the collection of microorganisms that live in the body) in preventing diseases led ARS scientists in East Lansing, MI, in collaboration with Michigan State University scientists, to investigate the potential role of the

microbiome in MD resistance. The results of this research showed differences in splenic T cells and the cecal microbiome in two genetically distinct varieties of chicken, one that was resistant and the other susceptible to MD. Interestingly, the composition of the microbiome was different between resistant and susceptible birds. When MD virus was administered to the chickens, both bird varieties demonstrated similar metabolic profiles, but there were differences between the two varieties in both amino acid and lipid metabolism. These results provide insights into differences in the immune response of MD-resistant chickens and potential interplay with the microbiome during infection with an oncogenic virus. Information on the role of the microbiome in preventing diseases may be used in the future to reduce the loss from MD.

**Presence of vaccine-derived Newcastle disease viruses in wild birds.**

The loss of ecological species barriers, which permits opportunistic pathogens to cause disease in wildlife (i.e., animals that are not susceptible to an infectious agent provide a natural barrier for other animal species), is a major factor influencing disease emergence in wild birds. ARS scientists in Athens, GA, in collaboration with University of Georgia scientists, found vaccine-derived Newcastle disease viruses (NDV) from different species of wild birds across four continents from 1997 through 2014. The data indicate that at least 17 species from 10 avian orders occupying different habitats excrete vaccine-derived NDV. Examining the extent of spillover of live vaccines such as NDV from poultry into wild birds is crucial because the downstream epidemiological consequences of such spillovers are still unknown. Circulating live vaccine viruses could present additional risks such as reversion to virulence and recombination with wild-type strains. In addition, the immune response of wild birds induced by infection with vaccine strains may result in greater virulence. The finding of live

attenuated NDV in other avian species provides important evidence that the use of these vaccines should be monitored to assess their potential effect on the environment and the emergence of new viral strains.

**A better understanding of avian viruses with zoonotic potential in Pakistan.**

Significant economic losses from poultry death and decreased egg production have resulted from infections caused by H9N2 low-pathogenic avian influenza virus (LPAIV) across North Africa, the Middle East, and Asia. This group of viruses has also caused sporadic infections in mammals, including humans, and has been associated with some specific genetic changes that suggests increasing pandemic potential. The H9N2 LPAIVs have been endemic in Pakistani poultry since 1996, but no new viruses had been reported since 2010. Because novel genotypes of Pakistani H9N2 contain mammalian host-specific markers, ongoing surveillance is essential to better understand any continuing public health risk. ARS scientists in Athens, Georgia, in collaboration with Pakistani scientists, reported this year the characterization of four new H9N2 LPAIVs, three found in 2015, and one found in 2012. All of the viruses tested in this study originated in the Middle East. Importantly, these viruses all contained mammalian host-specific markers, suggesting that Pakistan avian H9N2 viruses have the capacity to infect mammals. This information underscores the continued need to undertake surveillance in poultry and mammals to monitor the spread of these and other influenza strains and understand the potential for zoonotic infections.

**Automated vaccine delivery system to improve biosecurity in poultry houses.**

Traditional methods of vaccinating poultry often involve an operator entering the poultry house to spray vaccine using a backpack-mounted device, which increases the likelihood of pathogens being

inadvertently brought into the barn and thus, greater biosecurity risks. Although vaccines are often added to poultry water supplies, contamination can also occur when this method of vaccination is used. To solve these problems, ARS scientists in Mississippi State, MS, developed a new, fully automated system for spraying vaccines inside poultry barns. The system triggers birds to drink from water locations using changes in lighting. After the birds approach a water source, vaccine spray nozzles are lowered from the ceiling and the birds are sprayed. The nozzles are strategically placed above the water source to ensure the birds receive maximum coverage. The target is the animal's eye area, where scientists know that vaccines are easily absorbed, but birds will also pick up the vaccine through preening and contact with other birds. The scientists compared the performance of the automated system against a three-person vaccination crew with backpack sprayers using a combination of infectious bronchitis and Newcastle disease vaccines. The results of blood samples taken from automatically vaccinated flocks showed improved immune protection against the viruses compared with the backpack method. In addition, biosecurity risks and the number of personnel required to vaccinate a flock were also both reduced.

#### **Detection of classical scrapie prions in the brains of goats.**

Scrapie is a transmissible spongiform encephalopathy that causes fatal neurodegenerative disorders in goats and sheep. Real-time quaking-induced conversion is a rapid, specific, and highly sensitive detection assay used to detect low levels of abnormal scrapie prion proteins. Although this sensitive assay has been used successfully to detect abnormal prion proteins in various tissues from humans and animals, including sheep, tissues from goats infected with scrapie have not yet been tested. ARS scientists in Pullman, WA, in collaboration with scientists at Washington State University, evaluated whether abnormal prion proteins could be detected in the brain tissues of goats with scrapie using this

sensitive assay and compared its performance with more commonly used prion-detection methods. ARS scientists further optimized assay conditions for sensitive and specific detection of goat scrapie in clinical animals. The results from these studies provided good discrimination between scrapie-infected and normal goat brain samples. Importantly, these studies indicated that this highly sensitive assay was at least 10,000-fold more sensitive than the commonly used prion detection methods for the detection of scrapie activity in goat brain samples.

### **Using genomics to identify novel antimicrobials.**

A critical need exists in animal agriculture to develop new antimicrobials and alternative strategies that will help to reduce the use of antibiotics and address the challenges of antimicrobial resistance. High-throughput gene expression analysis is providing new ways to enable the discovery of host-derived antimicrobial peptides. One example of these peptides are the NK-lysins that were first described in mammals and are also found in avian species. The peptides have been shown to have antimicrobial activities that could potentially be used to control important poultry pathogens. ARS scientists in Beltsville, Maryland, demonstrated alterations following chicken NK-lysins binding to coccidia and *Escherichia coli* membranes, indicating damage and disruption of cell membranes, suggesting that NK-lysins kill pathogenic protozoans and bacteria by direct interaction. DNA analysis revealed that chicken NK-lysins peptides derived from certain genes were more effective at killing pathogens than those derived from other genes, which could potentially result in certain genetic lines of poultry being more resistant to diseases. Although these host-derived antimicrobial peptides may not by themselves be able to replace the antibiotics currently used in animal production, their use as specific treatments on the basis of their known mechanisms of action is showing promising results.

**Senecavirus A is one of the causative agents of swine vesicular disease.**

Idiopathic vesicular disease in swine is a diagnosis made when none of the other pathogens known to cause swine vesicular disease (e.g., vesicular exanthema virus, swine vesicular disease virus, vesicular stomatitis virus, and foot-and-mouth disease virus) have been detected. Occasionally, an emerging virus called Senecavirus A (SVA) has been detected in cases of idiopathic vesicular disease, raising the possibility that SVA infection could cause vesicular disease in swine. For the first time, ARS scientists in Ames, Iowa, in collaboration with scientists at Iowa State University, have been able to experimentally induce clinical signs and gross lesions in nursery-age pigs inoculated with SVA, demonstrating a causative relationship between SVA infection and vesicular disease in susceptible pigs. This knowledge is helping animal health experts understand pathogenicity and disease transmission and provide the means to test experimental vaccines that could be used to prevent the disease.

**Rumen microbial community changes milk production efficiency.**

The efficiency of conversion of feed to milk (production efficiency) is a major factor affecting how the U.S. dairy industry impacts the environment, economics, and food supply of the country. Dairy cows vary in milk production efficiency, but only part of the variation among cows is explained by cow genetics. Dairy cows also have different communities of microbes in their rumens. In an effort to determine how these differences affect production efficiency, ARS researchers in Madison, Wisconsin, and collaborators performed near-total exchange of rumen contents between high- and low-efficiency cows, and showed that these exchanges respectively decreased or increased milk production efficiency of each cow for about 7 days before returning to their previous levels; additionally, after the rumen digesta exchange, the species composition of the rumen bacterial community gradually returned to a

composition similar to the original unique profile of each host cow. The results directly implicated the rumen bacterial community as determinants of milk production efficiency. Improvement of milk production efficiency with its concomitant decrease in environmental impact and improvement in farm return over feed costs may be possible if factors controlling the rumen microbial community can be optimized.

### **Identification of markers associated with susceptibility to liver abscesses.**

Liver abscesses are found at processing in approximately 13 percent of cattle being fed high-energy density rations, as this diet makes them more susceptible to infection from rumen bacteria that generate acid conditions in the digestive tract. The acidosis and associated liver abscesses seldom result in outward clinical signs, but they reduce carcass weight and quality and cost the processor \$20 to \$80 per affected animal in lost revenue. The prevalence of abscesses will likely increase as the use of antibiotics for promoting growth decreases. Also, because the abscesses are not outwardly detectable, there is a need for alternate management practices to prevent them. ARS researchers in Clay Center, Nebraska, identified 35 genetic markers associated with abscess susceptibility and detailed their study in a peer-reviewed journal. These genetic markers may be useful in genetic selection programs to reduce the incidence of disease.

### **Glucosamine supplementation during late gestation increases sow litter size.**

Litter size in swine is a component of the efficiency of the breeding herd. Previous studies indicated that glucosamine supplementation beneficially altered placental development, but subsequent studies on commercial sows indicated that glucosamine had equivocal effects on litter size. ARS researchers in

Clay Center, Nebraska, in collaboration with an industry partner, demonstrated that supplementation of sow gestation diets with 20 grams (.7 ounces) of glucosamine per day during the last third of pregnancy increased litter size by more than 1 piglet per litter born alive. The increase in litter size did not reduce average birth weights or preweaning survival. Routine supplementation of sow diets with glucosamine would contribute to improved reproductive efficiency in sow herds and improved profitability of swine production.

**Expanded national genomic evaluation service for dairy cattle.**

Dramatic increases in the effectiveness of genetic selection in dairy cattle have been accomplished through genomic analyses, but the process is ongoing and many more traits could be added. Control of the dairy cattle national database and responsibility for routine delivery of genetic evaluations was transferred from ARS in Beltsville, MD, to the Council on Dairy Cattle Breeding. A copy of the CDCB database is maintained at ARS to allow expanded research on genetic evaluation development and methodology, and CDCB employees interact with ARS on a daily basis. The arrangement allows CDCB to continue expanding data collection and services to the dairy industry, while ARS staff focuses on research. Projects completed jointly by ARS and CDCB include exchange of Holstein bull genotypes with Switzerland (March 2016) and Japan (May 2016); genomic prediction of breed composition (June 2016); and expansion of genomic evaluations to Guernseys as a fifth dairy cattle breed (April 2016) in cooperation with the United Kingdom and the Isle of Guernsey. The collaboration between ARS and the dairy industry has produced a world-leading genomic prediction system and a vast database that producers in about 50 countries now use routinely to accelerate genetic progress and select parents who can produce healthier, more productive dairy cattle.

**A phytoestrogen produced by red clover reduces ammonia production in the rumen in steers.**

Feeding high-quality protein to ruminants to improve growth efficiency is limited in utility because of the degradation of amino acids by rumen microorganisms, which also increases the release of ammonia to the environment. Reducing the excretion of ammonia would reduce the environmental impact of the herd. Biochanin A, a phytoestrogen derived from red clover, inhibits hyper-ammonia-producing bacteria that degrade protein and adversely affect amino acid profiles entering the small intestines. ARS scientists in Lexington, Kentucky, conducted a grazing experiment with steers feeding on pastures of mixed cool-season grasses. Adding biochanin A to a dried distillers grain protein supplement as part of the animals' feed significantly increased average daily weight gain over the pasture-only control treatment. Additionally, Biochanin A inhibition of hyper-ammonia-producing bacteria increased cellulolytic bacteria, which might play a role in increasing ruminal degradation of fiber. Biochanin A benefits animal performance by improving the quality of digested protein and digestion of dietary fiber.

**Altering forages improves nitrogen use efficiency.**

The chemical composition of forages consumed by dairy cattle affects feed intake and milk production, as well as the composition of manure and its impact on the environment. Improvements in the efficiency of feed nitrogen use and reduced urinary nitrogen loss can reduce feed cost and the environmental impacts of milk production. ARS researchers in Madison, WI, determined that feeding polyphenolic-containing forages, such as birdsfoot trefoil and red clover, and tannin extracts to lactating cows enhanced the efficiency of feed nitrogen use by the cow and reduced the excretion of urea in urine. This, in turn, reduced losses of ammonia and nitrous oxide (the most potent agricultural greenhouse gas)

from dairy farms. This information has been highlighted in important popular press outlets and was featured in an international symposium, spurring ongoing tannin research internationally.

**Identifying novel antimicrobials to target *Clostridium perfringens*, a poultry pathogen.**

*Clostridium perfringens* is a major disease-causing bacterial pathogen in poultry, a source of food poisoning and gas gangrene in humans, and which can cause mild to severe disease in pigs. Lessons from Europe suggest that the coming FDA ban on the unrestricted use of antibiotic growth promotants in animal feed will result in increased incidence of diseases associated with *Clostridium*, so alternative strategies are needed against this pathogen. An ARS scientist in Beltsville, MD, has examined the genomes of 43 *Clostridium perfringens* isolates from chicken, and identified bacteriophage (viruses that infect bacteria) genomes embedded in the genomes of the bacteria. Hundreds of genes for putative phage enzymes that disrupt bacterial cells were identified using molecular biological tools. Four of these enzymes were tested and shown to kill all 43 of the *Clostridium perfringens* isolates in lab assays but did not have a deleterious effect on other Gram positive or Gram negative species tested. This is an important step toward identifying novel replacements for antibiotic growth promotants that can be added to poultry feed.

**Public release of an improved goat genome assembly.**

Genome studies in livestock species have made significant advances in eliminating deleterious mutations and improving production traits difficult or expensive to measure. These studies were made possible by the reference livestock genome sequence assemblies that were made in the preceding decade, but further improvements would increase the utility of the genome sequences. ARS scientists in

Beltsville, MD, and Clay Center NE, working in tandem with members of the National Human Genome Research Institute, BioNano Genomics, Phase Genomics, and the PirBright Institute (based in the United Kingdom) have used the latest long-read sequencing technology available at Clay Center to create and release an improved reference genome assembly of the domestic goat. The assembly is more than 250 times better in contiguity (a key measure of quality and utility), when compared to the previous public reference genome. The improved reference genome is supporting advances in genome analysis and identification of biomarkers by ARS and collaborator scientists.

**Discovery of genomic locations controlling number of milk glands in swine.**

Litter size in commercial swine populations has increased steadily for the past decade; however, the number of milk glands in the udder of sows has increased at a slower pace. The number of milk glands in pigs is a heritable trait and has become economically important due to this imbalance. ARS scientists in Clay Center, Nebraska, conducted a genome-wide association study for genes affecting the number of milk glands in their commercial swine population. Thirty-three genomic regions were discovered that affect the number of milk glands, representing 39 percent of the genetic variation present in a validation population similar to contemporary commercial sows. The identification of genetic markers within these regions will enable the swine industry to increase teat numbers in commercial populations and reduce the need for cross-fostering and artificial rearing, which should improve piglet survival.

**Online prediction of pork loin quality with the model VQG pork loin grading camera.**

The National Pork Board is considering development of a pork grading system, and grading cameras can accurately assess meat quality more consistently, thus reducing inherent variation in human subjective

evaluation. ARS scientists in Clay Center, NE, in collaboration with Texas Tech University, determined that loin color, marbling, water-holding capacity, and tenderness could be predicted with on-line assessment of loins with the model VQG pork loin grading camera. This updated camera system is based on a system that ARS helped develop, and the scientists are working with the pork industry to incorporate its use into their operations. Implementation of this tool will allow the industry to identify higher quality pork that could be marketed in a premium program.

**Beef cattle breeds differ in feed efficiency.**

Feed cost represents one of the highest variable input costs in beef cattle production systems. Selection of animals able to grow faster or eat less feed or both (i.e., increased feed efficiency) could substantially reduce producer costs. In addition to selection, utilization of breeds with high feed efficiency could increase profit prior to selection strategies. Knowing which breeds have the greatest feed efficiency could help producers in making their breeding decisions. ARS researchers, using data from the germplasm evaluation program in Clay Center, Nebraska, derived differences in heifer and steer feed intake and gain for 18 different beef cattle breeds.

**Management options for lambs and meat-goat kids on pastures in the United States.**

In the United States, lamb and meat goat production is growing rapidly to supply animals for many ethnic markets. However, internal parasite control is a significant management challenge for producers. ARS scientists in El Reno, Oklahoma, along with colleagues at West Virginia University, Michigan State University, and Virginia Tech, finished lambs and meat goats on grass-clover pastures with and without whole cottonseed supplement. Lambs and meat-goat kids given the supplements had improved

weight gains and better tolerance to internal parasites. Combining cottonseed supplementation with an internal parasite-resistant breed of lamb (Katahdin) and a selective deworming program of individual animals resulted in the least number of dewormer doses given to animals. This information is useful for producers looking to reduce reliance on dewormers for more sustainable production of lamb and meat goats for niche markets in the United States.

**Identification of a key metabolic change in pigs that reduces growth rate.**

Slow-growing pigs result in a \$90 million loss to the swine industry each year. The metabolic factors responsible for poor postnatal growth rate in some normal birth weight pigs is not understood. ARS scientists in Beltsville, MD, analyzed the metabolic activity of the livers from pigs with low growth rates that demonstrated no changes in carbohydrate or normal fat metabolism. However, the expression of genes associated with an unusual form of fat metabolism, lipid peroxidation, was discovered to have increased in livers of slow growing pigs. This is significant because peroxidation results in damage to cells that reduces growth and development, processes critical for growth in the young pig. This research identifies a key change in metabolism in the slow-growing pig that will permit development of nutritional and nutraceutical intervention to promote improvements in growth and well-being of these pigs.

**A genomics component for the Animal-GRIN information system.**

Prior to development of the genomics component of the Animal-GRIN (Germplasm Resources Information Network), the livestock research community did not have a mechanism to permanently store genotypes derived from publically funded livestock genomics work. As a result, the long-term security

of expensive data was at risk and it was difficult for other researchers to access and leverage this information in other experiments. An ARS-led team developed a genomics component as part of Animal-GRIN Version 2. With this component, it is possible for public sector researchers to enter their genomic data into the database and for the community at large to have access to those genotypes. The developed component also makes available, for the first time, the linkage and access to genomic, phenotypic, management, and environmental information complete with a physical tissue sample from the individual animal. This work opens up public data to a broad range of users so they have the opportunity to leverage previous investments made in genotyping.

**A hormone receptor that controls testicular function in boars.**

Fertility of boars has an important impact on reproductive efficiency of swine herds. Most swine producers in the United States mate sows using artificial insemination, requiring an estimated 30 million doses of semen every year. There is a critical need to understand testicular function to develop methods to improve semen production and quality. ARS researchers in Clay Center, NE, in collaboration with researchers from the University of Nebraska, found that boars have a specific hormone receptor (GnRHR2) in special cell types within the testicle. When the receptor was activated, testosterone was increased, which is a steroid important for sperm production. These results indicate a role for this receptor in testosterone production and testicular function in boars. Because this research is basic to understanding the physiology of the animal, more work is needed to fully understand the role of the receptor in sperm production. Additional knowledge of that role could aid in improving boar fertility.

**Estrus-related fertility in estrous-synchronized beef cattle is mediated by uterine acidity.**

Cows that demonstrate behavioral estrus during an ovulation-induction (synchronization) protocol have greater fertility than cows that do not demonstrate behavioral estrus during this time. One mechanism by which greater fertility occurs may be changes in uterine pH to improve sperm survival. To test this, ARS researchers in Clay Center, NE, and South Dakota State University measured sodium/hydrogen transporter gene expression (controls intrauterine pH) and uterine pH in the hours prior to artificial insemination to examine their relationship to behavioral estrus and fertility. In cows that demonstrated behavioral estrus, sodium/hydrogen transporter abundance decreased, whereas there was no change in abundance in cows that did not demonstrate estrus. The findings demonstrated that decreased uterine pH was associated with increased conception to artificial insemination, and with additional research, may prove to be an important factor in the fertility of cows.

**An early warning system for Rift Valley fever (RVF).**

RVF is a devastating, mosquito-borne disease that affects both livestock and humans. Few opportunities exist to validate or evaluate warnings and control measures in areas where the risk of transmission is high. To better understand, validate, and evaluate the risk for transmission of RVF and other diseases such as Zika and dengue, ARS scientists and several U.S. Government colleagues studied the potential for outbreaks of this disease in Kenya and developed models based on key environmental signals. Alerts produced by the ARS-developed outbreak warning system compelled the government of Kenya to conduct a mass vaccination of domestic livestock, thereby possibly averting a major outbreak of the disease.

**Evaluating pesticide application methods to control Zika vectors.**

The capability of larvicide sprays to penetrate into buildings or through vegetation where mosquitoes may be resting or hiding is not well known. ARS researchers in Gainesville, FL, in partnership with the Florida Army National Guard, investigated the efficacy of liquid larvicide against mosquitoes that are responsible for the spread of Zika, chikungunya, yellow fever, and dengue viruses. The scientists compared spray applications of a larvicide that targets mosquitoes in a simulated urban environment to mimic conditions in Florida, a hot-arid desert environment as one would find in California, and a dry-season tropical environment typical in Thailand. Results indicated poor penetration into buildings and vegetation in all three environments, even when sprayed at point-blank range. These field trials demonstrate that it may not be possible to effectively control these mosquitoes with traditional methods, but instead, they will require techniques and formulations that have not yet been tried or discovered.

**Novel formulation of a vaccine against cattle fever.**

Cattle fever is a devastating disease transmitted by cattle fever ticks. New technologies are desperately needed to keep the United States free of cattle fever ticks because they are becoming resistant to chemical treatment and new ticks are being brought into the United States on a variety of different animal hosts. The first doses of a new anti-cattle fever tick vaccine were delivered to the Cattle Fever Tick Eradication Program. This resulted from more than 5 years of cooperative research and development among ARS researchers in Kerrville and Edinburg, Texas, and colleagues at several other institutions. This new vaccine formulation is now being used in an integrated vector control program to control the cattle fever tick.

**A new kit to identify fire ants.**

The imported fire ant quarantine has been in place since 1958, regulating the interstate movement of certain commodities in an effort to reduce the spread of imported fire ants. Rapid ant identification at border inspection stations and ports is critical to facilitate trade and commerce. A significant problem is that it is not always possible to identify fire ants because few specimens are collected and it is difficult to identify native and imported ants by physical examination. Researchers with ARS in Gainesville, FL, and their APHIS colleagues in Biloxi, MS, have developed a field-portable, rapid detection kit to identify imported fire ants. The kit requires no special training or equipment and takes only 10 minutes to confirm whether or not the ants are fire ants. APHIS plans to use the kits at interdiction sites to enforce the quarantine. In addition, regulatory agencies from other countries are interested in adopting the technology.

**Using integrated pest management technology to control invasive cane.**

Arundo cane is a non-native invasive plant species that is clogging portions of the Rio Grande River and reducing border visibility. ARS researchers in Edinburg, TX, developed an integrated pest management method to meet the needs of stakeholders along the Rio Grande River. The method integrates mechanized topping of Arundo cane at 3 feet followed by a release of biological control agents, thus providing immediate visibility of the international border for law enforcement agencies and, at the same time, long-term suppression of Arundo cane. An additional benefit from this practice is that it allows desirable native vegetation to thrive again in the treated area. This integrated pest management process has been transferred to vegetation managers at the U.S. Border Patrol and is being implemented widely on the Texas-Mexico border

**Ability of mosquito species to transmit diseases not currently present in the United States.**

For a very long time, Japanese encephalitis virus (JEV) has been transmitted by mosquitoes in tropical and subtropical regions of Asia. The transmission cycle involves domestic pigs and avian species that serve as amplification hosts; humans are incidental hosts that cannot develop a high-titer viremia sufficient to pass on to mosquitoes. In multiple Asian countries, people bitten by infected mosquitoes can suffer from severe neurological problems. The potential introduction of JEV into North America is a major threat to human and animal health. In this study, ARS researchers from Manhattan, Kansas, collected *Culex* mosquitoes from fields around Valdosta, Georgia, that were shown to be susceptible to JEV infection, suggesting the United States may be at risk of JEV transmission if the virus were to be introduced.

**Managing ammonia emissions from screwworm larval rearing media.**

Mass production and release of sterile screwworms are essential to the successful eradication of screwworms, an insidious and economically important pest in North America. The protein-rich diets required for larval screwworms led to high ammonia levels within a mass rearing facility in Panama. Addition of a combination of powder extract of *Yucca* and potassium permanganate resulted in lower ammonia levels. Lower ammonia levels and elimination of formaldehyde in the mass-rearing facility improves conditions for employees and results in a better quality of screwworms, the ultimate product of the facility.

**Bed bug defensive secretions attract adult bed bugs.**

Detection of bed bugs and monitoring for their presence are important first steps in any control strategy aimed at controlling these blood-sucking insects, yet there is no monitoring device in widespread use. Using a video tracking system, ARS scientists in Beltsville, MD, in conjunction with scientists at the University of Maryland, demonstrated that chemicals produced by bed bugs that were previously thought to be defensive secretions because they dispersed bed bugs, will actually attract adult male and female bed bugs when released at low levels. This information will be useful for commercial organizations that wish to develop cost-effective, reliable means of monitoring and detecting bed bugs.

**Horn flies can spread *Salmonella*.**

Insects have been implicated in the spread of microbial pathogens within livestock production systems, and this is important from animal and human health perspectives alike. In cattle, peripheral lymph nodes contaminated with *Salmonella* can be inadvertently processed along with the beef carcass, resulting in tainted beef products. The bacteria may be introduced to cattle by biting arthropods. ARS scientists identified the horn fly as a mechanical vector of *Salmonella* and demonstrated transmission of the bacteria to cattle peripheral lymph nodes due to feeding by horn flies. Improved fly management practices in livestock production systems are possible by using this knowledge to interrupt the horn fly feeding cycle and decrease the likelihood of *Salmonella* in beef.

**Novel botanically based biting fly repellent.**

Flies and other biting insects are annoying and potentially dangerous because of their ability to transmit diseases to humans and livestock. ARS scientists in Lincoln, NE, discovered novel anti-feeding and repellent compounds from a natural product, coconut oil. These compounds provided up to 2 weeks of repellency against biting flies, and 1 week against bed bugs and ticks. The compounds also stop mosquitoes from biting. Efficacy of these compounds is comparable, and in some cases better, than that of DEET, the best biting insect repellent commercially available.

**Gene silencing technology for mosquito control.**

There are very few public health pesticides available for controlling medically important vectors such as mosquitoes and sand flies. A novel approach to mosquito control is based on the technology that allows the specific silencing of genes that are critical to survival of the insect species. This technology uses double-stranded RNA (dsRNA) and the process of RNA interference (RNAi) to selectively silence gene products (proteins) that debilitate the mosquito vector and prevent disease transmission. ARS scientists and collaborators in Gainesville, FL, have demonstrated that targeted silencing of ribosomal proteins RPS6 and RPL26 reduced fecundity more than 88 percent in *Aedes aegypti* mosquitoes for the first oviposition cycle. Reduced fecundity continued through a second oviposition cycle, indicating a lengthy effective period from one treatment. These studies indicate that target selection, dsRNA format, dose, and tissue susceptibility are critical parameters that must be considered in the development of effective RNA-based pesticides to control mosquito vectors. Selectively silencing the production of particular proteins is an effective method for controlling mosquito vectors.

**Mosquito bite protection built in to U.S. Marine Corps uniforms.**

The bite protection of permethrin-treated U.S. military combat uniforms is usually evaluated for 50 wash cycles. This wash cycle end point was chosen on the basis of the expected life time of older, 100 percent cotton combat uniforms. The new combat utility uniforms for the U.S. Marine Corps are composed of 50 percent nylon and 50 percent cotton and last longer than 50 wash cycles. ARS researchers in Gainesville, FL, conducted bite protection studies of blouse and trouser uniform fabrics washed up to 150 times. The blouses provided 95 percent or better bite protection after 120 wash cycles, whereas the trousers fell below 95 percent after 50 wash cycles. These data establish that uniforms remain intact after 150 wash cycles and for blouses, the treatment is very efficient at preventing bites after 130 washes. This information will be used by the U.S. Marine Corps to better understand the bite protection provided by permethrin-treated uniforms when they are washed up to 150 times.

**Using genomics to improve disease resistance in rainbow trout.**

Bacterial cold water disease (BCWD) of rainbow trout is a continuing challenge to the American aquaculture industry, being responsible losses up to 39 percent in hatchery stocks. ARS researchers in Leetown, WV, aimed to improve disease resistance in fish using genome-based breeding instead of traditional pedigree-only breeding and have shown that the genome predictions are substantially better at selecting traits that confer resistance to BCWD over successive generations of fish. Using this relatively new process of genomic selection will likely reduce the amount of time, money, labor, and the number of fish needed to achieve the same level of improvements. Applying a similar genomic selection strategy to improve other commercially important animal traits, including resistance to other diseases,

increased fillet yield, or improved carcass quality offers opportunities to increase farm productivity, enhance product quality, improve animal welfare, and improve the overall sustainability of rainbow trout production systems.

### **Evaluation of algal sources of omega-3 fatty acids to replace fish oil in trout feeds.**

Fish oil is derived from capture fishes such as sardines and menhaden, and has been the traditional source of omega-3 fatty acids in feeds for farmed fish such as trout. However, the limited availability of fish oil from natural resources is currently limiting the expansion of aquaculture production, which aims to provide healthy protein sources to a growing global population. ARS researchers in Aberdeen, ID, determined the nutrient digestibility, palatability, and functionality of a number of new commercial sources of algae that are high in omega-3 fatty acids. All algal products exhibited high digestibility of omega-3 fatty acids, with no effect on feed intake, and minimal effect on feed manufacturing.

Identifying alternative sources of omega-3 fatty acids for aquaculture feeds that do not reduce production efficiency or product quality, such as these algae, will decrease our dependence on ocean-harvested fish and remove production barriers to increasing the availability and sustainability of this heart- and brain-healthy protein source.

### **Improving the diet of commercial catfish.**

Farm-raised catfish have the highest economic value of any domestic aquaculture industry; in 2013, 605 farms produced more than 350 million pounds of food-sized fish valued at more than \$350 million. Fish feeds constitute half the cost of production; therefore, understanding the nutrient requirements of this fish is essential to maintain the competitiveness of this industry. Catfish feeds are plant-based and can

feature high levels of phytate or phytic acid, a compound that binds iron and other minerals, making them unavailable to fish. ARS scientists in Auburn, AL, and Stuttgart, AR, collaborated with colleagues at Auburn University and demonstrated that coating feed with the enzyme phytase, which destroys phytate, and could boost the uptake of iron and other key nutritional minerals. Scientists also showed that fish given the phytase-treated diet had higher red blood cell and hemoglobin counts, increased growth rates, and a greater ability to convert iron and other minerals in the digestive tract into useable forms that can be deposited into the blood stream. Phytase is currently used in poultry and swine diets to destroy phytate. These results suggest that phytase-amended diets could improve both the health and production of farmed catfish.

**An oral vaccine for enteric septicemia of catfish increases profitability.**

*Edwardsiella ictaluri* is the causative agent for enteric septicemia of catfish, a highly fatal systemic infection that is responsible for significant economic losses in the catfish industry. Researchers from Mississippi State University in collaboration with ARS scientists in Stoneville, MS, conducted commercial field trials with a previously patented oral vaccine to prevent septicemia. Vaccination was shown to dramatically improve fish production, resulted in improved animal health and growth rates, and in commercial fish farm trials increased gross sales by approximately \$3,000 per acre for channel catfish and \$2,000 for hybrid catfish (i.e., a 30-percent to 50-percent increase over sales for non-vaccinated fish populations). In 2015, more than 90 million fingerlings were vaccinated on 6 commercial operations.

**A DNA-based tool for managing trout production.**

In salmonid aquaculture, family-based selective breeding programs rely on accurate pedigree information for selecting the best breeding animals. In addition, breeding companies that provide eggs to grow-out farmers need a way to trace a fish's pedigree from the farm back to the breeding population of origin to help resolve issues associated with suboptimal production. ARS researchers in Leetown, WV, developed a new, inexpensive DNA-based assay and demonstrated that it can be used to rapidly and effectively analyze parentage with 100 percent accuracy and assign production fish back to their population of origin with 97 percent accuracy. ARS has made this new assay available to Troutlodge, Inc., the largest trout breeding company in North America, and it is currently being offered as a commercial product by the Center for Aquaculture Technologies, Inc., an aquaculture biotechnology company. This assay provides a means for breeding companies to trace fish genetics as part of a strategy to resolve issues associated with suboptimal production efficiency.

**New feed processing technology results in better water quality for fish farms.**

Feeding fish with traditional feeds results in fecal particles that are very fine and difficult to settle or remove by filtration in flow-through or recirculating aquaculture systems. Fish feeds are traditionally held together in a pellet with carbohydrates. ARS researchers in Aberdeen, ID, developed a new method that does not require carbohydrates. This new technology, which has been patented, results in fish producing larger and more durable feces that can be more easily removed from the water, thus improving water quality by reducing nutrients in the effluent. Adoption of this new processing technology will enhance the water quality of aquaculture production.

**Using genetics to improve the eastern oyster for commercial production.**

Improving the eastern oyster through genetic manipulation is expected to make it more economically feasible to produce on a commercial basis. ARS scientists in Kingston, RI, and their collaborators conducted field trials to evaluate the growth, mortality, and yield of six mass-selected oyster populations at five farm sites with varied environmental conditions. Significant genetic and environmental interactions were detected for mortality and yield, and peak mortality at each site coincided with the most prominent oyster pathogen at that site. Selected varieties generally performed best at their native site, and some varieties exhibited above average performance at multiple sites. Characterization of interactions between oyster varieties and the environments in which they are raised will enhance current breeding efforts that aim to increase production efficiency and profitability of shellfish farming while improving the quality and availability of shellfish products to United States consumers.

**Fish meal in hybrid striped bass diets can be replaced with high-protein, low-antigen soy varieties.**

Replacing fish meal as a protein source in fish feeds has the potential to reduce an aquaculture farmer's reliance on fish meal and increase the availability of farmed fish products. ARS researchers in Stuttgart, AR, and collaborators at several institutions [University of Arkansas (UA) at Pine Bluff, UA at Fayetteville, ARS Trout-Grains Project, Hagerman, ID, and the U.S. Fish and Wildlife Service Fish Technology Center, Bozeman, MT] previously conducted nutrient digestibility studies in hybrid striped bass using three novel varieties of non-genetically modified soybeans containing higher protein and lower anti-nutritional factors than traditional soybean. Recently, these varieties were used to replace all the fish meal in a typical commercial hybrid striped bass feed in a performance trial to assess growth, body composition, intestinal health, immunological response to soy antigens, and resistance to disease.

Results indicate that fish meal can be entirely replaced by high-protein, low-antigen soybean meals when formulated on an available amino acid basis and supplemented with limiting amino acids.

**Sire strain affects blue × channel catfish progeny performance in commercial settings.**

Hybrid catfish created by mating blue and channel catfish are the preferred fish produced by the U.S. farm-raised catfish industry, which relies primarily on the D&B and Rio Grande strains of blue catfish. ARS scientists in Stoneville, MS, examined the influence of blue catfish sire strain (D&B versus Rio Grande) on hybrid catfish embryo production and fingerling performance under commercial hatchery conditions. Average testis weight, an indicator of reproductive efficiency, was higher in Rio Grande fish compared with that of D&B fish. However, D&B hybrids exhibited higher rates of mean survival, production, and growth efficiency compared with Rio Grande hybrid catfish fingerlings reared in earthen ponds. This research demonstrates the potential of exploiting genetic differences between strains to increase production on commercial farms.

**Genetic diversity of *Flavobacterium psychrophilum* isolates from the United States determined by multilocus sequence typing.**

Bacterial cold water disease (BCWD) is a frequent cause of freshwater-farmed trout loss, and genetic diversity of the pathogen is poorly understood. ARS researchers in Leetown, WV, in collaboration with scientists at the College of Veterinary Medicine, Michigan State University, and French National Institute for Agricultural Research, identified 96 isolates of *F. psychrophilum* recovered from rainbow trout, coho salmon, and Chinook salmon that originated from 9 States. Multilocus sequence typing (a molecular technique used to characterize DNA sequences) was used to identify 34 types of the bacteria

that clustered into 5 groups. A specific sequence was commonly associated with BCWD outbreaks on rainbow trout farms. This information improves our understanding of genetic diversity and strains associated with bacterial disease outbreaks, which will help direct the development of targeted vaccines, and improve a farmer's ability to select disease-resistant rainbow trout.

**Atlantic salmon can be raised to market weight in land-based systems using sustainable diets.**

The use of alternative protein sources in fish feed continues to increase as concerns persist surrounding the availability and cost of using ocean-harvested fish as protein and oil in fish feed. Furthermore, commercial farms are beginning to use land-based systems that recirculate water and allow production of market-size Atlantic salmon with less disease and without perceived negative effects on the marine ecosystem. Researchers at The Conservation Fund's Freshwater Institute in Shepherdstown, WV, showed that a novel fishmeal-free diet fed to Atlantic salmon in recirculation aquaculture systems resulted in greater waste production, but equal salmon growth, feed conversion, and survival compared with a traditional fishmeal-based diet. These findings were adapted to larger scale salmon production, for which ARS provided the first evidence that Atlantic salmon can be effectively raised to market size while consuming a fish meal-free diet in a commercially relevant land-based system. This research provides strategies for infrastructure and rearing that are expected to increase Atlantic salmon production efficiency, alleviate environmental impacts of fish that escape land-based farms, and reduces reliance upon capture fisheries.



## **NATURAL RESOURCES AND SUSTAINABLE AGRICULTURAL SYSTEMS**

### **National Programs:**

- **Agricultural System Competitiveness and Sustainability, NP 216**
- **Water Availability and Watershed Management, NP 211**
- **Climate Change, Soils, and Emissions, NP 212**
- **Pasture, Forage and Rangeland Systems, NP 215**
- **Biorefining, NP 213**
- **Agricultural and Industrial Byproducts, NP 214**

### **Risk assessment tool for landscape management.**

Rangelands are vulnerable to soil erosion, runoff, and other damaging environmental processes, and prediction technologies are critical for managing rangeland resources. ARS scientists in Tucson, AZ, developed the Rangeland Hydrology and Erosion Model (RHEM) tool to evaluate and illustrate how different rangeland conditions can affect the risk of excessive rangeland runoff and soil erosion. Users can program this Web-based tool to run alternative scenarios for a particular rangeland site, including a user-defined “baseline” scenario, optimal scenarios, or alternative scenarios. The program uses the baseline scenario for a specific site to project low, medium, high, and very high yearly erosion rates and then produces comparable estimates for other scenarios. This tool will greatly facilitate the development

of formal Ecological Site Descriptions used by the Natural Resources Conservation Service, Forest Service, and Bureau of Land Management to characterize the hydrologic and vegetation functions of land resources, particularly for grazing lands.

**New software helps prioritize sites for dam rehabilitation.**

More than 11,800 flood-control dams have been constructed across the United States since 1948. Many are nearing the end of their planned life span of 50 years, and some need rehabilitating to ensure their continued functionality. ARS, Kansas State University, and the Natural Resources Conservation Service (NRCS) developed and released Windows Dam Analysis Modules (WinDAM C), a Common Computing Environment (CCE)-certified software that incorporates algorithms developed by ARS scientists for predicting embankment dam failure because of internal erosion and embankment overtopping. This technology is designed to help dam-safety engineers in NRCS, the Tennessee Valley Authority, the Federal Energy Regulatory Commission, and other Federal and State agencies identify embankment dams that are in the most urgent need of repair and rehabilitation. Dam experts in Brazil, Spain, and the United Kingdom have also expressed interest in using WINDAM C.

**Center pivot irrigation helps rice producers reduce water use and expand production.**

Traditional U.S. rice production includes flooding rice fields for much of the growing season, but soil type and topography limit where flood management can be used. Following up on earlier research, ARS researchers at Portageville, MO, and collaborators demonstrated that center pivot irrigation schedules could be successfully adapted for rice production on coarse-textured soil characterized by high water

infiltration rates. Rice is a food staple in much of the world, and these results will help rice producers optimize center pivot irrigation to reduce their water use on coarse soils.

**Drought-, salt-, and boron-tolerant crops extend water resources by using alternative, lower quality water resources.**

Extreme drought conditions increase the importance of identifying drought-, salt-, and boron-tolerant plants that can grow in saline soils and adapt to irrigation with degraded water supplies. But continuing droughts can increase soil saline content via groundwater contamination, so even tolerant plants will require good quality water to offset the increased salinity in the growing environment. Working in California's San Joaquin Valley, ARS scientists conducted field trials with mustard, poplar-tree clones, and *Opuntia* cactus to assess how drought impacts plant health in this environment. They found that excessive drought exacerbates the challenge of developing sustainable production systems with plants that can tolerate saline soils and irrigation with degraded waters. The use of alternative drought-, salt-, and boron-tolerant crops is, however, essential as an alternative farming practice for growers who have limited high quality water in the Western United States.

**Water capture and sub-irrigation can help offset crop water needs associated with climate change.**

Midwest U.S. climate change projections indicate that crop water deficits will increase and adversely impact production. Sub irrigation, in which water is captured from crop fields and subsequently delivered to the plant root zone from below the soil surface, could help offset these water deficits. ARS researchers in Columbus, Ohio, and colleagues used historical sub-irrigated field crop yield data to determine an overall estimate of future northwest Ohio sub-irrigated field crop yield increases, based on

climate projections for 2041 to 2070. They found overall field corn yields rising from an actual value of 20 percent in 1996-2008 to an estimated yield of between 27 and 30 percent in 2041-2070, while field soybean yields were estimated to improve from 12 percent in 1996-2008 to around 20 percent for 2041-2070. These findings suggest that as drought becomes more frequent, using agricultural water capture and sub-irrigation systems to boost crop yields could provide a viable climate-adaptation strategy to help sustain agricultural production.

**New "blind" inlet conservation structure design reduces pesticide runoff.**

Conventional tile risers improve agricultural productivity by draining excess water from low spots such as potholes, but they also increase pesticide levels in runoff. ARS scientists at West Lafayette, IN, conducted a 6-year field study conclusively demonstrating that blind inlets can reduce pesticide losses in runoff. Blind inlets reduced atrazine losses by 57 percent, alachlor losses by 58 percent, metolachlor losses by 53 percent, and glyphosate losses by 11 percent. These findings demonstrate that blind inlets can enhance water conservation efforts by reducing pesticides and sediment in drainage runoff.

**Variable rate irrigation management saves water.**

Crop water requirements can vary within a single field because there can be considerable variation in soil properties and plant characteristics. Variable rate irrigation (VRI) technology applies irrigation water at variable rates at specific sites within a single field. ARS scientist at Stoneville, MS, conducted a 2-year field study in the Mississippi Delta to compare VRI management with conventional uniform rate irrigation (URI) management. They found that VRI yield was equivalent to URI yield, but VRI management reduced irrigation water use by 25 percent. Irrigation water use efficiency for soybean and

corn under VRI was 25 percent and 27 percent higher, respectively, than in URI water use efficiency. These findings indicate VRI management could be used to conserve irrigation water supplies in humid production regions.

### **The GOES Evapotranspiration and Drought (GET-D) Product System.**

The GOES (Geostationary Operational Environmental Satellite) Evapotranspiration and Drought (GET-D) Product System passed Operational Readiness Review by the National Oceanic and Atmospheric Administration (NOAA) in January 2016 and became operational June 6, 2016. The GET-D system is based on remote-sensing approaches initially developed by ARS scientists in Beltsville, MD. It will produce daily maps of evapotranspiration (ET) and an associated Evaporative Stress Index (ESI) over North America at an 8-km spatial resolution. These routine ET and ESI products will be used within NOAA's drought monitoring and land-surface modeling programs and additionally disseminated through the National Integrated Drought Information System (NIDIS). This project is an example of multi-agency collaboration in which ARS models transitioned to operational production at NOAA. It was funded in part by NASA's Applied Sciences program (see <http://www.ospo.noaa.gov/Products/land/getd/>).

### **Integrated remote sensing system maps crop growth at field scales.**

Crop growth information can help farmers in scheduling irrigation, fertilization, and harvest. Local farmers provide USDA's National Agricultural Statistics Service (NASS) with weekly reports on crops and conditions at the State and district levels, but ground data collection is time consuming, highly localized, and produces inconsistent data quality. While remote sensing can provide timely and

consistent large-area coverage, standard products based on only one satellite lack either the spatial or temporal resolution needed for robust monitoring at field scale. ARS scientists at Beltsville, MD, developed an integrated remote-sensing system to map crop growth using remote-sensing data from multiple satellite platforms. Near-daily vegetation indices at 30-m spatial resolution were produced for monitoring crop progress and condition. Further, these time-series datasets were used to deduce key crop growth stages (e.g., emergence, maximum green-up, and harvest) over agricultural landscapes. This information is critical for monitoring the growth and development of crops and will be used by NASS to provide improved in-season monitoring of domestic agricultural production.

**Watershed planning tool simplifies finding sites for conservation practices.**

Siting conservation practices can be ineffective and costly because current watershed models do not adequately simulate processes associated with gullies, wetlands, and riparian buffers in the context of an agricultural watershed. ARS scientists at Oxford, MS, collaborated to release the watershed planning tool AnnAGNPS v5.44, which contains enhanced gully, wetland, and riparian buffer components for developing integrated conservation management practice watershed plans. The AnnAGNPS watershed modeling tool helps evaluate the potential of conservation practices for reducing pollutants on a watershed scale, which helps watershed conservation managers determine the most cost-effective locations for conservation practices.

**New approach sustains water resources for irrigation.**

The Lower Mississippi Valley, one of the most intensively irrigated agricultural landscapes in the country, is where 65 percent U.S. rice and 20 percent of United States cotton is produced. However,

irrigation demands have rapidly depleted groundwater across the alluvial valley. ARS researchers developed a novel approach to supplement Mississippi groundwater resources for irrigation using a combination of stream capture, bank filtration, and groundwater injection. The concept would supplement groundwater recharge by using subsurface technology to capture water from a major river, using bank filtration to improve water quality, and transferring the water to a region of critical groundwater decline, where it will be injected where it is most needed. Stakeholders have strongly supported this approach, and a pilot project will be constructed in 2017. Results from this project could become a major component in solving increasing water demands in the lower Mississippi valley.

**Less expensive regional water and soil salinity assessments aid water and land management during drought.**

Soil salinity reduces the productivity and profitability of farmland in arid and semi-arid regions, and is particularly problematic during droughts. Satellite remote sensing is one of the only feasible methods for assessing agricultural productivity, water consumption, and soil salinity at regional scales. ARS researchers in Riverside, CA, developed new capabilities for regional-scale assessments, including (i) new satellite remote-sensing techniques for mapping root zone salinity at regional scales; (ii) a simplified methodology for mapping soil salinity at field-to-landscape scales; and (iii) new techniques for incorporating satellite-based estimates of evapotranspiration and groundwater storage changes into land-surface models. The new salinity maps and remote-sensing techniques should help in assessing and mapping water use and soil salinity at regional and State levels, which are essential for identifying and understanding drivers and trends in water use and salinity and for developing management plans and mitigation strategies. The cost-effective methodology can be used by government agencies; international

partners with limited resources; and water and land resource managers, producers, agriculture consultants, and extension specialists.

**Improved Soil and Water Assessment Tool (SWAT) supports next-generation Conservation Effects Assessment Project (CEAP).**

CEAP has a mandate from the Office of Management and Budget to evaluate the effectiveness of U.S. conservation programs and policies, and SWAT models are a key part of that effort. The new SWAT+ model has enhanced features that facilitate incorporating larger national-scale datasets and assessing local connections among landscape and water features. These features include national climatic and crop management data; a detailed stream network and water feature data that are under review; and the use of aerial photography to conduct a nationwide survey of more than 15,000 sites with conservation practices and/or gullies. All of these data and models are being released online as they become available.

**Improving soil moisture satellite processes for enhanced land and water management.**

Accurate soil moisture remote sensing is crucial for providing soil moisture data globally at a spatial resolution that supports a wide range of agricultural, hydrologic, and climate applications. The Soil Moisture Active Passive (SMAP) mission is a National Aeronautics and Space Administration (NASA) satellite mission launched in 2015 that can potentially meet this need. During FY2016, ARS scientists played a critical leadership role in providing ground-based testing and algorithm improvements needed to ensure sufficient soil-moisture retrievals. They led a ground and aircraft validation campaign around the Walnut Gulch Experimental Watershed near Tombstone, AZ, during the 2015 summer monsoon to

collect ground truth data for satellite soil-moisture retrievals. Data analysis in 2016 enabled SMAP algorithm revisions for monitoring soil moisture in semi-arid domains, such as the southwestern United States. This will improve the understanding of climate and weather dynamics in a drought prone region of significant interest to the U.S. Department of Agriculture and the National Oceanic and Atmospheric Administration.

### **Remote monitoring of water stress in wine grape.**

U.S. wine grape production is a \$5 billion industry. Mild to moderate water stress optimizes wine grape fruit yield and quality, but precision irrigation management is hindered by the lack of a reliable method to easily quantify and monitor vine water status. ARS researchers in Kimberly and Parma, ID, used canopy temperature measurements and artificial neural network modeling to calculate the crop water stress index (CWSI) of two wine grape varieties managed with deficit irrigation. They found that daily CWSI was consistently different between deficit irrigation amounts, irrigation events, and rainfall, indicating that the neural network model predicted water stress. This methodology has been incorporated into a wireless network for two vineyards to provide daily CWSI values. These data will be used to verify that this irrigation management is resulting in measurements of optimal water stress levels more frequently and more easily than traditional manual wine grapevine water stress measurements.

### **Recent tree die-off has little effect on streamflow.**

Over the last two decades, beetle infestations have killed billions of trees and affected millions of acres of forest in the Rocky Mountains. Many of these forests are at the headwaters of rivers vital to western U.S. water supplies. ARS scientists in Tucson, AZ, collaborated with others to measure and compare

annual streamflow following tree mortality with 25 to 40 years of pre-mortality streamflow. Scientists observed only small overall changes, including both increased and decreased streamflow. They found dieoff reduces the amount of precipitation intercepted by forest canopy and taken up by plant roots, which increases precipitation contributions to streamflow, and it also increases snow sublimation and evaporation, which reduces precipitation contributions to streamflow. These results are consistent with recent studies of forest hydrologic processes and indicate that streamflow from forested headwaters is resilient to tree die-off. Ongoing research to predict the net effect of these trade-offs will improve water supply prediction and inform adaptive management of forested watersheds.

**Agricultural residues improve bioreactor nitrate removal at low temperatures.**

Nitrates lost from crop fields via drainage are a significant agricultural pollutant. In the Upper Mississippi River Basin, nitrate losses from agricultural fields are highest in spring when temperatures are low and flow rates are high. These factors slow the rate at which nitrate is biologically removed by woodchip-based bioreactors via microbial denitrification. ARS scientists in St. Paul, MN, and Ames, IA, compared how effectively wood chips and crop residues (corn cobs, corn stover, and barley straw) removed nitrates in early spring (1.5°C) and summer (15°C). The nitrogen removal rates for agricultural residues, which contain higher bacterial populations, were higher than for woodchips. Residue removal rates were much lower at the colder temperature, suggesting that dissolved carbon availability limited denitrification. Policymakers, engineers, and field technicians can use these results to design denitrifying bioreactor management that enhances nitrate removal.

**A new modeling framework for watershed simulations.**

Assessing how watershed dynamics are affected by a range of environmental and anthropogenic variables requires the ability to integrate and model biophysical responses, environmental problems, policies, economic activity, and subsurface and surface watershed datasets. A team of ARS scientists at El Reno, OK; Bushland, TX; Temple, TX; and Texas A&M University in College Station, TX, linked the Soil and Water Assessment Tool and Modular Three-Dimensional Finite-Difference Groundwater Flow models to improve hydrologic and water quality simulations in the surface and groundwater domains. They developed a new application tool called SWATmf and found it generated simulated streamflow and groundwater levels that generally agreed with observations. These results indicate SWATmf can be used for simulating surface and groundwater interactions. The integrated modeling framework is expected to improve watershed-scale model simulations and provide a modeling platform that resource managers can use to better understand linked surface-subsurface hydrologic processes and associated transport phenomena under time-variant conditions.

**Improved mapping for variable-rate irrigation.**

Variable rate (or precision) irrigation offers the potential to improve the efficiency of center pivot irrigation. Variable rate irrigation systems are commercially available, but they are not widely used because producers need better tools to develop irrigation application maps. Scientists in Florence, South Carolina, found that generating maps using remotely sensed corn-canopy data resulted in maps that were similar to maps generated with more labor-intensive methods that involve soil water monitoring devices.

These findings could be used by farmers, consultants, and industry in managing variable-rate irrigation systems, reducing labor costs, and conserving water.

**Pharmaceuticals accumulation in wheat irrigated with reclaimed municipal wastewater.**

Because of increased water-supply demands, wastewater treatment plant (WWTP) effluent is often used to irrigate agricultural lands. Emerging contaminants such as pharmaceuticals and personal care products (PPCPs) are frequently found in effluent due to limited removal during WWTP processes. An ARS scientist and partners analyzed the uptake of three antibiotics (sulfamethoxazole, trimethoprim, and ofloxacin) and the anticonvulsant carbamazepine in wheat plants that were spray irrigated with WWTP effluent. Very low levels of each compound were found on most plant surfaces. Ofloxacin was found throughout the plant with higher concentrations in the straw and much lower concentrations in the grain. Very low levels of trimethoprim were only found on grain or straw surfaces, while much lower levels of sulfamethoxazole and carbamazepine were concentrated within the grain. These findings demonstrate that very low levels of PPCPs can be taken up into plant tissue and adhere to plant surfaces when WWTP effluent is spray irrigated. The results will be used to safely increase water supplies by showing that some drugs found in wastewater used for irrigation accumulate mainly in the non-edible portions of the wheat.

**Strip-tilling sugar beet maintains yield and increases infiltration.**

About half of U.S. sugar comes from sugar beet. ARS researchers in Kimberly, Idaho, compared sugar beet production between strip tillage and conventional tillage under full and deficit irrigation. Sugar yields were similar for both tillage practices under all irrigation amounts. However, strip tillage is \$50

to \$75 less expensive per acre because of lower tillage costs and increased water infiltration. Using strip tillage can reduce production costs and increase irrigation efficiency while maintaining sugar beet yield.

**Soil temperature effects successfully modeled.**

Irrigated crops consume a large portion of freshwater resources, but irrigation can result in yields that are up to four times larger than yields from non-irrigated crops. Producers need information about crop water use to improve irrigation management, but crop water use is linked to many factors, including how much the soil beneath a crop is sunlit or shaded. Scientists from ARS laboratories in Bushland, TX, Beltsville, MD, and Ben-Gurion University of the Negev, Israel, developed and tested a new mathematical model that improves estimates of soil sunlight and shade beneath a row crop. These improved estimates can increase the efficiency and cost-effectiveness of irrigation water management, increase crop yields, and help conserve freshwater resources.

**Reducing bias in evapotranspiration reference maps.**

Accurate information about daily reference evapotranspiration (ET) is needed for efficient water management from field to regional scales. To meet this need, scientists at National Oceanic and Atmospheric Administration (NOAA) use data from non-agricultural weather networks to develop daily reference ET maps for the contiguous United States. These maps can help improve models of water demand and availability. ARS scientists from Bushland, TX, NOAA, the U.S. Geological Survey, and Texas A&M AgriLife Research used data from the agriculture-based Texas High Plains ET network to evaluate the accuracy of the NOAA reference ET maps. Results showed that the NOAA reference ET values were generally higher than observed values from the Texas High Plains ET network. These

findings suggest that NOAA may need to add a correction factor for air temperature and wind speed data to increase the accuracy of its reference ET maps.

**Grass strips do not contribute to riparian restoration of agricultural headwater streams.**

Planting grass filter strips is a common agricultural conservation practice that is believed to help restore riparian habitats. It is critical to understand how these grass filter strips affect the riparian structure and function of agricultural streams to determine if this management helps restore riparian habitats adjacent to agricultural headwater streams, particularly degraded sites. ARS researchers studied the effects of grass filter strips and determined they did not significantly differ from unplanted riparian habitat in structure and function. They also found that forested riparian habitats had more structural diversity and functional levels, such as lower water temperature, greater organic matter, and species diversity, than herbaceous riparian habitats. These results indicate that planting grass filter strips does not help conserve and restore riparian habitats adjacent to channelized agricultural headwater streams. Action agencies can use this information to modify policies and approaches for managing riparian habitats adjacent to agricultural streams and enhancing natural resource conservation

**Multi-objective model calibrations using water balance.**

Automated procedures are often used to provide fits between hydrologic model estimates and observed data, but they may not accurately represent the basic hydrologic characteristics of the watershed itself. ARS researchers at Tifton, Georgia, worked with collaborators to develop a method that included discharge and individual water balance components to evaluate criteria for calibrating hydrological models. Their findings indicate that using statistical measures to simulate discharge dynamics and

magnitude does not result in a reasonable simulation of the hydrological system and that the range of water balance components can be constrained to achieve a more realistic simulation.

**Energycane: a successful bioenergy feedstock for Louisiana.**

A successful bio-based economy will require the sustainable production of high quality biomass crops. ARS scientists conducted a 5-year study in southern and northern Louisiana and obtained energycane yields ranging from 12 to 23 tons of dry biomass per acre using minimal management (no irrigation water and reduced tillage practices). Energycane was available for industrial conversion from August to March each year. These results demonstrate that Louisiana can reliably produce high yielding and sustainable feedstocks for potential bioenergy industrial partners.

**Soil profiling and subsurface imaging using seismic surface waves.**

Non-invasive soil profile measurement and subsurface soil imaging are important for agricultural applications such as measuring soil mechanical and hydraulic properties, detecting soil layers such as plowpan and fragipan, and evaluating soil surface erosion (surface crusting/sealing). ARS scientists in Oxford, Mississippi, and collaborators developed a technique to non-invasively measure one-dimensional soil profiles and two-dimensional images of subsurface soil in the vadose zone. This technique assesses shear wave velocity associated with soil strength, water content, and water potential. The method has been successfully applied to study how soil responds to seasonal and weather conditions, detect plowpan and fragipan, and evaluate surface crusting/sealing. Natural resource managers can use this tool to improve soil conservation efforts and assess soils for potential crop protection.

**Spring frost protection in cranberry farms.**

Irrigating cranberries is key to preventing spring bud damage, but this requires large quantities of water. Scientists at University of Massachusetts and ARS evaluated a water-conserving irrigation method to determine its effectiveness in protecting cranberry buds from spring frost. They found the new technology uses from 35 to 77 percent less water than conventional irrigation and is equally as effective as conventional irrigation in frost protection.

**Enhanced-efficiency nitrogen fertilizers can reduce nitrous oxide emissions.**

A portion of the nitrogen fertilizer that is applied to crop soils can be lost as nitrous oxide gas, which is also a potent greenhouse gas. ARS researchers in Kimberly, ID, monitored greenhouse gas emissions from a silage corn–barley–alfalfa rotation that received a stabilized urea fertilizer (SuperU) or conventional granular urea in the spring, or dairy manure in the fall or spring. They found that SuperU reduced nitrous oxide emissions by 52 percent when corn was grown, but nitrous oxide emissions were not reduced when barley was grown. In all cases, nitrous oxide emissions from the soils were less than 1 percent of the applied nitrogen. However, nitrous oxide emissions were slightly higher when manure was applied, but the season of application did not impact the amounts emitted. This work demonstrates that SuperU can reduce nitrous oxide emissions from selected (i.e., corn) irrigated cropping systems in the semiarid Western United States, which can help reduce greenhouse gas emissions from agricultural operations.

**Increasing soil carbon sequestration and reducing carbon dioxide emissions with conservation tillage.**

Financial constraints and the lack of long-term research projects have limited studies of soil carbon sequestration rates and other changes in soil chemical properties under long-term conservation and conventional tillage. ARS scientists at Florence, SC, created a 34-year tillage and crop management experiment on sandy soils. They found that it took a few decades to accumulate a significant amount of topsoil organic carbon, but that over the 34-year study, conservation tillage resulted in a net accumulation of about 7 metric tons per hectare of soil organic carbon, compared to conventional tillage. During the 34-year course of this experiment, 25 metric tons of carbon dioxide equivalents per hectare were sequestered. These results affirm that conservation tillage management can benefit United States producers by increasing soil organic carbon content and reducing greenhouse gas emissions from agricultural production.

**The Greenhouse Gas Reduction through Agricultural Carbon Enhancement network (GRACEnet) project.**

While U.S. agriculture has historically been a significant source of greenhouse gas (GHG) emissions, agricultural soil management practices have been developed and are under continued development that curtail these emissions. As a result, it has been demonstrated that many U.S. agricultural soils now sequester significant levels of the GHG carbon that might otherwise have been emitted into the atmosphere. The primary objective of GRACEnet is to identify, develop, and improve agricultural practices that will enhance carbon sequestration in soils, promote sustainability, and provide a sound scientific basis for carbon credits and related environmental markets. Major GRACEnet products

include establishing field/laboratory measurement protocols; creating a standardized Excel data entry template; developing software for data entry quality control; creating a web-accessible GRACEnet/Resilient Economic Agricultural Practices (REAP) database with field measurements, site characterization data and land management information; and the publication of over 800 journal articles/book chapters with project results. GRACEnet data have increased the accuracy of soil GHG emission estimates reported in the U.S. national GHG inventory and have been used to develop factors imbedded in decision-support tools to quantify the GHG benefits of improved management practices. In addition, GRACEnet data have been used to validate the underlying models used by the NRCS COMET-Farm decision- support tool, a program agricultural producers can use to calculate how much carbon their conservation actions can remove from the atmosphere.

**Improved nutrient management for reducing nitrous oxide emissions.**

Strategies have been proposed for reducing nitrous oxide emissions by modifying different aspects of nitrogen fertilizer management. These modifications have included altering application rates and changing the source/type of nitrogen fertilizer and/or the timing or placement of nitrogen fertilizers. Studies have shown that modifying only one of these components by itself does not consistently reduce nitrous oxide emissions. ARS scientists in Saint Paul, MN, conducted field studies over two corn growing seasons to examine a variety of nitrogen fertilizer management combinations that altered the fertilizer rate, application timing, and/or use of microbial inhibitors. They found that management that involved multiple changes (split fertilizer application schedules, microbial inhibitors, and a reduced nitrogen fertilizer application rate) was able to decrease nitrous oxide emissions. These results demonstrate that many changes to conventional farming practices will be needed to effectively reduce nitrous oxide emissions.

**Earthworms play important roles in soil ecology.**

Earthworms are responsible for a number of important processes in soil modification and restructuring—they decompose surface litter, move organic matter from the surface down into the soil, digest and decompose soil organic matter, and create tunnels that alter soil porosity. Earthworms are often divided into functional groups based on their feeding and burrowing behaviors, and it is assumed that all species within each functional group will have similar effects on soil organic matter. ARS researchers in Beltsville, MD, found that certain earthworm species within these functional groups affected these processes differently. For example, some species within each functional group had different impacts on soil microbiological activity, the incorporation of surface litter into soil organic matter, and changes in the abundance of soil bacteria and fungi. These effects varied according to the specific earthworm species, highlighting the need to incorporate species information into studies on earthworms and soil organic matter. These results will be useful to soil ecologists and may lead to strategies for managing earthworms and other soil biota in improving the sustainability of agroecosystems.

**Crop residue improves fall precipitation capture.**

In the Mediterranean-type climate of the Pacific Northwest, thick layers of crop residues are often left on fields at harvest, but they are not effective in preventing significant amounts of evaporation over the summer fallow period. Historically, these residues are often removed or tilled into the soil. Using weighing lysimeters, field plots, and samples from farmers' fields, ARS researchers at Pendleton, OR, learned that residue cover approaching 100 percent is very effective at improving deep penetration and storage of early fall rains. Residue cover of less than 50 percent, however, was much less effective, and

moisture from small rain events would often evaporate completely. Since small rain events are very important to wheat yields in semi-arid areas, this information has encouraged farmers to develop ways to maintain residue cover and to plant through higher levels of residue cover and to abandon management practices that remove residue from the field. In addition to yield increases, these practices will help protect soil quality and provide improved climate resilience.

### **Integrated remote sensing for retrieving field-scale leaf area index.**

Leaf area index is a key parameter used in land surface flux estimates, water resource management, and crop growth monitoring. Current coarse resolution leaf area index tools (at the kilometer scale) are sufficient for global, continental, and regional-scale applications. Agricultural field-scale applications, however, require leaf area index with both high spatial and temporal resolution. ARS scientists in Beltsville, MD, have developed an automated mapping method for leaf area index that generates a 4-day time-series of a 30-meter leaf area index. This method was tested over central Nebraska from 2002 to 2012 and showed promise for using data from current satellites to generate frequent map leaf area indices at field scales. This approach demonstrates potential for crop modeling at field scales, which is information needed by the National Agricultural Statistics Service for crop condition monitoring and yield estimates.

### **Fungi increase drought tolerance in wheat.**

Abiotic stresses, particularly drought, reduce wheat grain yields in many semiarid regions of the world. However, in the inland Pacific Northwest of the United States, patches of green and vibrant spring wheat have been observed to grow in the midst of wheat stunted by severe water stress, even during periods of

extreme drought. This growth was supported in part by plant interactions with arbuscular mycorrhizae (AM), which allowed wheat to accumulate greater amounts of limited water. ARS scientists in Pullman, WA, determined that drought appears to have enhanced AM relationships with wheat, which suggests that inoculating seeds or soil with AM fungi may help increase grain yield during drought.

**Continuous cropping systems increase soil carbon and reduce carbon dioxide emissions.**

Most cropping systems in the Pacific Northwest dryland production region are losing soil organic carbon over time. Soil conservation requires the development of productive farming systems that also preserve soil carbon. ARS researchers in Pendleton, Oregon, used field experiments and models to measure and predict how different cropping system options affect soil carbon. They found that using no-till management in continuous winter wheat production increased soil organic carbon and also reduced carbon dioxide emissions. These results will encourage the development and adoption of continuous winter wheat cropping systems, improve soil quality, and reduce greenhouse gas emissions from agricultural production.

**Cattle play a major role in grassland ecosystem nutrient cycling.**

ARS researchers in Ft. Collins, CO, and Colorado State University collaborators studied the effects of cattle excrement patches on nitrous oxide and methane fluxes in both cool-season pastures and warm-season native rangelands in a northern Colorado shortgrass steppe ecosystem. Measured nitrous oxide emissions from manure nitrogen were substantially lower than the default emission values established by the Intergovernmental Panel on Climate Change (IPCC) for manured pasture. These findings suggest that IPCC default values significantly overestimate nitrous oxide and methane emissions from both the

shortgrass steppe native rangeland and cool-season pasture during drought. This indicates the need to improve IPCC simulations to increase the accuracy of its estimates of agricultural contributions to greenhouse gases.

**Soil physical structure is a key factor in greenhouse gas emissions.**

Understanding the processes that control greenhouse gas (GHG) emissions is critical for developing mitigation practices to reduce these emissions from agricultural activities. ARS researchers in Saint Paul, MN, evaluated the factors influencing GHG emissions rates under field and laboratory conditions. The data showed that 72 percent of the variability was explained by soil physical properties, which suggests that the soil physical structure is the major factor in determining the GHG emission potential of a particular soil. These results are significant for farmers and policymakers and will assist scientists and engineers in developing improved models for predicting net GHG emissions.

**Plants and growing media affect soil carbon dynamics.**

There has been little work on how plants growing in urban areas (~148 million acres) mitigate climate change via carbon storage. ARS scientists grew three common ornamental shrubs (cleystera, Indian hawthorn, and loropetalum) in containers using three potting substrates: pinebark (industry standard), clean chip residual (a forestry operations byproduct), or WholeTree (another forestry operations byproduct). After one season, the plants were transplanted into the landscape and soil carbon dioxide flux was monitored by an automated carbon dioxide efflux system (ACES) for 1 year; plant growth and soil carbon were also measured. The scientists found that soil carbon dioxide flux was not affected by plant type or substrate. However, they noted that pinebark plots had higher soil carbon levels, indicating

that it decomposed more slowly and has greater soil carbon storage potential than the two alternative substrates. These results indicate that urban landscapes have a large carbon storage potential that could help mitigate climate change.

### **Wind erosion and climate change in the Pacific Northwest.**

Warmer and drier climates predicted for the coming decades could impact agriculture and wind erosion in the Pacific Northwest. PM<sub>10</sub>, microscopic particulate matter less than or equal to 10 microns in diameter, is often a respiratory risk and is of particular concern in the Pacific Northwest. This is because PM<sub>10</sub> emissions from agricultural lands can cause elevated atmospheric concentrations of the particulates that at times exceed National Ambient Air Quality Standards. ARS scientists at Pullman, Washington, and University of Idaho collaborators simulated climate change impacts on wind erosion and emissions using state-of-art climate forecasts and wind erosion technologies. They found that, even with the projection of a warmer climate, wind erosion and PM<sub>10</sub> emissions in the Pacific Northwest are predicted to decrease by 2050, largely as a result of enhanced biomass production that will protect the soil from erosion.

### **Humic products support the growth of corn roots.**

Humic product vendors often claim their products promote crop root growth, which would enable crops to take up water and nutrients more quickly and potentially contribute to soil carbon stocks and erosion control. But there are no formal data to support these vendor claims, so ARS researchers in Ames, Iowa, measured corn root growth in highly controlled studies over 3 consecutive years to determine if the use of humic products affected growth. In most cases, root length increased with product application by at

least 15-20 percent by the final sampling time, with most of the root growth stimulation occurring later in the growing season. Proportional increases in root biomass were the same as or greater than root length, which suggests that the roots became denser or thicker as a result of the product applications. Initial findings that long-term applications of humic products improve soil physical properties suggest that humic products might give farmers an option for mitigating the detrimental effects of intensive agriculture on soil health.

**Soil & Water Assessment Tool (SWAT) model measures how winter cover crops affect water quality.**

Resource managers need to know the extent to which winter cover crops can affect water quality throughout an entire watershed. As part of the Conservation Effects Assessment Project (CEAP), ARS scientists in Beltsville, MD, used the Soil & Water Assessment Tool (SWAT) model to evaluate the effect of winter cover crops on reducing nitrate loads into the streams within Maryland's Choptank River watershed. Their results indicated that SWAT showed promise as a management tool for evaluating these impacts and for assessing cover crop impacts on improving water quality. These findings suggest that the validated SWAT model can be used by agricultural producers and regulatory agencies throughout entire watersheds and basins for assessing how winter cover crop production improves water quality.

**Corn residues harvest changes soil hydrology and soil aggregation.**

Reducing or eliminating tillage is recommended when crop residues like corn stalks are harvested. However, information is lacking on whether conservation tillage strategies are sufficient to protect soil

resources when residues are aggressively harvested. ARS researchers in Morris, Minnesota, and collaborators compared soil aggregation and water infiltration in fields with and without tillage, and with no residue harvest or maximum residue harvest. Soils in tilled fields were more exposed to wind and water and had reduced ability to capture rainwater. Fields managed without tillage captured and stored more rainwater when residue covered the soil. This work will aid producers, energy industry, and action agencies balance the pros and cons of harvesting crop residues such as corn stalks for bioenergy.

**Amending soils with biochar affects herbicide stability and activity.**

Biochar is a coproduct that results from the conversion of plant material to biofuel via pyrolysis. Amending soils with biochar may increase soil nutrients and water holding capacity, but field application of biochar may also have unintended consequences for other crop management practices, such as how well herbicides work. ARS researchers at Brookings, SD, and university collaborators examined how biochar application affected the availability of the herbicides atrazine and 2,4-D in soil and how biochar affects the speed of plant germination. Soils amended with biochar produced from corn stover, switchgrass, and Ponderosa pine retained 5 to 10 times more herbicide than untreated soils, with only modest differences due to biochar type. Plants that are typically affected by these herbicides germinated more rapidly when biochar was present. These data indicate that amending soils with even small amounts of biochar can increase herbicide retention in soils but at the same time reduce the herbicide's potential effectiveness against weeds. Site-specific biochar applications may be needed to obtain optimal benefits without compromising other agronomic practices.

**Cover crops affect the soil microbiome.**

Cover crops are used in sustainable agricultural systems to suppress weeds, scavenge nutrients, and add organic matter to the soil. Some cover crops can also supply nitrogen to subsequent cash crops. Cover crops have been shown in past studies to affect soil microbiomes, but results varied depending on which cover crops were used and if they were incorporated into the soil or left on the surface. ARS researchers in Beltsville, MD, examined how the selection and management of eight different cover crops affected soil microbiomes. They found that cover cropping increased soil microbial biomass and that different cover crops had different impacts on the soil microbiome. Oat and rye cover crops increased arbuscular mycorrhizal fungi (AMF), which improve water and nutrient uptake in many crop plants, while hairy vetch increased fungi other than AMF. These results support efforts to evaluate the use cover crops to manage the soil microbiome and enhance soil health.

**Arbuscular mycorrhizal (AM) fungus increases tomato yields.**

Arbuscular mycorrhizal (AM) fungi improve water and nutrient uptake in many different plants. In a 7-year study, ARS researchers in Wyndmoor, PA, found that adding AM fungi to tomato seedlings increased average yields by around six percent at an average cost of less than a penny per plant. These results indicate that AM fungi may provide tomato producers with a cost-effective way to increase tomato yields.

**Rising temperatures linked to rising carbon dioxide levels will reduce rice yields.**

ARS scientists in Beltsville, MD, studied a wide range of commercial and wild rice germplasm (e.g., varieties) to evaluate the impact of increased temperatures and higher concentrations of atmospheric carbon dioxide on rice yields. All the rice varieties in the study responded to rising carbon dioxide levels with reduced seed yields, and increased temperatures caused a more severe impact. However, the scientists observed that some wild rice varieties were less affected by these conditions than the commercial varieties. This suggests that some wild rice varieties may contain genes that could be used to develop robust commercial lines that can be better adapted for food production under changing climate conditions.

**Adding biochar to soil as a management strategy.**

The benefits of biochar for improving soil health may depend in part on its interactions with soil microbes. This is because there is growing evidence that biochar can be degraded by soil microbes and that it also modifies microbial abundance, community composition, and activity. ARS researchers in Fort Collins, CO, and collaborators in China studied different rates of biochar addition to soils and found that 90 percent of biochar added to soil remained in the soil after 30 months, no matter how much biochar was initially incorporated into the soil. They also observed links between biochar decay rates and soil organic carbon levels, which suggests that soil microbes use biochar as a carbon source only after supplies of accessible soil organic carbon are exhausted. These findings suggest that typical biochar field application rates benefit the soil microbial community and that biochar additions will decay very slowly in soils – even those that lack continuous inputs of fresh soil carbon.

**Less nitrogen fertilizer needed for optimum sugar beet yield.**

Nitrogen management is critical in sugar beet production to optimize overall crop yield and the amount of sugar that can be extracted from the beet. Current nitrogen fertilizer recommendations for sugar beet in Idaho are 7 pounds of nitrogen per ton of beet. ARS researchers in Kimberly, ID, and cooperators used 14 site-years of data to determine that current nitrogen requirements for Pacific Northwest sugar beet production could be reduced 14 to 29 percent and that producers could achieve maximum sugar yield if they apply an average of 4.5 pounds of nitrogen per ton of beet. These new recommendations will provide farmers with significant cost savings and reduce nitrogen losses to the environment.

**No-till increases crop residue harvest sustainability.**

Crop residues like corn stover perform important functions that promote soil health and provide ecosystem services that influence agricultural sustainability and global biogeochemical cycles. However, harvesting corn stover for livestock feed, bedding, and cellulosic ethanol production has been rising and is expected to increase. In a 4-year study, ARS scientists in Brookings, SD, evaluated how corn residue removal from a no-till corn-soybean rotation affected crop yields, greenhouse gas (GHG) fluxes, and net global warming potential. Corn and soybean grain yields were not significantly affected by residue removal. Residue removal did not significantly affect GHG fluxes from corn; however, significantly higher nitrous oxide fluxes (107 percent) were observed in soybean when crop residues were removed. All field plots were a net source of methane throughout the study. Soil organic carbon increased in both treatments during the study, but lower accumulation rates were observed in plots where corn residue was removed. Since all plots had net soil organic carbon gains, both treatments exhibited negative net global warming potential. These findings indicate that no-till management and

biennial corn stover harvesting under local agronomic and climate conditions do not increase global warming potential. However, they also suggest that repeated corn residue harvesting may increase nitrogen loss from fields as nitrous oxide emissions. These data fill specific knowledge gaps for life cycle analyses of regional bioenergy cropping systems.

**Hydrology drives nitrogen loss from sandy southeastern soils.**

Strip tillage helps conserve soils and is generally considered an effective method for reducing surface runoff, erosion, and related losses of nitrogen, which is an agricultural pollutant of concern. However, ARS scientists at Tifton, GA, found that strip tillage facilitated increased subsurface flows, and this increased flow resulted in an overall twofold increase in nitrogen loss. Conventional tillage resulted in greater surface runoff losses, but strip tillage resulted in greater subsurface losses. Much of the subsurface flow occurs from January through April, when soil saturation is high and evapotranspiration rates are low. Nitrogen losses were largely due to the effects of tillage type on hydrologic routing, not from the amount of nitrogen in the runoff. This study demonstrates that although reduced tillage is effective at reducing surface runoff and erosion, it introduces new challenges for nutrient management because it can lead to enhanced infiltration that may lead to increased nitrogen losses in subsurface flow.

**Crop rotations for soil fertility and sustainable agriculture.**

Developing sustainable crop rotations requires understanding complex relationships between soils, crops, and yield. To better understand these relationships, scientists at the North Central Agricultural Research Laboratory in Brookings, SD, measured how simple and complex crop rotations (including row crops, annual forages, and perennial forages) affected soil characteristics, corn and soybean growth,

and grain yields. Rotating corn cropping with wheat or alfalfa produced a higher corn grain yield than a simple corn/soybean rotation, although seed nitrogen concentration was only significantly greater in rotations containing alfalfa. Treatments that included alfalfa rotations resulted in soybean seed yield increases of around 10 percent and seed protein concentration increases of around 3 percent. The alfalfa rotations may have increased soil nitrogen levels that in turn resulted in increased seed yields and seed nitrogen levels. These findings suggest that alfalfa cropping could increase soil nitrate levels and allow northern Great Plains farmers to reduce nitrogen fertilizer rates by 45 percent and still maintain yields in some rotations. Maintaining crop yields while reducing nitrogen fertilizer application rates would increase farm profitability and reduce nitrogen loss from farm fields. These findings provide greater insight into how cropping systems affect agroecosystem function and response.

**Long-term crop rotation and tillage impacts on corn, grain sorghum and soybean.**

Long-term cropping system, tillage, and nitrogen fertilizer studies are essential for understanding production potential and yield stability of corn, grain sorghum, and soybean in rain-fed environments. ARS scientists in Lincoln, NE, conducted field studies in the western Corn Belt to evaluate how different tillage practices, crop rotations, and nitrogen fertilizer affect grain yield. Their findings suggest that across a wide range of weather conditions, corn and soybean production is more affected by crop rotation than by tillage management. Results indicate that using two- and four-year crop rotations in rain-fed environments can result in high-yielding, more stable corn, grain sorghum, and soybean grain production, compared with shorter rotations or continuous cropping under no-tillage.

**Visual soil structure evaluation helps assess sugarcane production sustainability.**

Increasing global demand for biofuel has accelerated land-use change in Brazil, primarily through sugarcane cultivation on degraded pastures. ARS scientists in Ames, IA, collaborated with visiting scientists from Brazil to evaluate the potential of using Visual Evaluation of Soil Structure (VESS) to assess how sugarcane production practices affect soil health and soil quality. Based on a scale of 1 to 5 (1 being best) the average VESS scores for native vegetation, pasture, and sugarcane were 2.0, 2.7, and 3.1, respectively, and the VESS scores accurately reflected laboratory measurements of soil physical properties. This suggests that VESS scores can be reliable indicators of soil structural quality in tropical soils. A VESS score of 3.0 is suggested as a warning point for changing current management to practices that enhance soil quality and structure in Brazilian soils used for crop production.

**Manure affects atrazine degradation more than antibiotics.**

The routine use of herbicides in grain production systems where soils are also amended with manure will result in the co-application of veterinary antibiotics (VAs) and herbicides to field soils. ARS scientists conducted a laboratory study and found that breakdown of the herbicide atrazine was somewhat reduced in experimental soils containing two VAs, sulfamethazine and oxytetracycline. But atrazine breakdown was significantly reduced in experimental soils containing both manure and VAs. This suggests that other manure components had a greater inhibitory effect on atrazine breakdown than the VAs. Additional soil microbial ecology assessments indicated manure amendments had a much more significant impact on soil community structure than VAs. These findings suggest that VA residues in land-applied manure are unlikely to alter atrazine fate in soil, and that herbicide persistence will not

be greatly affected by land application of manures that contain VAs when manure is used as a fertilizer source.

### **A new tool for metagenomics data management.**

The advent of next-generation sequencing has led to a dramatic increase in metagenomics analyses of microbial populations. These analyses range from vastly different environments (e.g., from soils to the human digestive system) and are being conducted by a variety of different researchers. However, current analysis platforms do not support convenient storage, standardization, or normalization protocols needed for efficient technology transfer and cross-study analyses. ARS scientists in Fort Collins, CO, developed myPhyloDB, a new Web-based local server that provides an easy-to-use graphical interface for storing metagenomics data in a SQL database and that allows users to standardize, normalize, and analyze data from multiple projects. The standardization, normalization, and analytic capabilities of myPhyloDB add new functionality to the DNA-sequence-processing capabilities of Mothur, the most widely cited bioinformatics program (4,000+ citations). The first version of myPhyloDB has been downloaded or distributed via CD-ROM to more than 60 users who work in fields ranging from soil microbial ecology to human health and nutrition.

### **Dedicated energy crops and crop residues for bioenergy feedstocks in the Central and Eastern United States.**

Bioenergy feedstock production in an agroecoregion must have a limited impact on the production of major crops while providing adequate and reliable feedstock supplies. ARS scientists in Lincoln, NE, concluded that Corn Belt production will benefit from major breeding advancements for perennial

grasses, biomass sorghum, and the agronomic management of corn stover for cellulosic biomass. In this region, adding perennial grasses into current agricultural systems reduces nutrient escape from fields to surface and ground waters, reduces greenhouse gas emissions, and increases soil carbon sequestration. In the Southeast, breeding advancements have been made in feedstocks including energycane, biomass sorghum, and napiergrass. Energy crop production provides unique opportunities for cultural change, operational diversification, and increased biodiversity on the agricultural landscape, but it needs to be profitable and must fit into existing farming operations.

### **Quantifying hydrogen and odor emission from animal systems.**

Hydrogen sulfide gas from swine manure slurries represents a health risk and odor nuisance, and increasing the use of dried distillers' grains with solubles (DDGS) in swine diets has contributed to increasing levels of hydrogen sulfide emissions. ARS scientists in Ames, IA, conducted an animal feeding trial that investigated how sulfur levels and sulfur sources in swine diets affect hydrogen sulfide emissions. They found that increasing sulfur levels in swine diets significantly increases hydrogen sulfide emissions and odor and that diets enriched with sulfur amino acids also increase sulfur odor emissions. Another study demonstrated that the composition of animal feed can increase hydrogen sulfide and odor emissions. Information from these studies will help growers, engineers, and regulatory officials develop guidelines for alternative diets with reduced sulfur levels, which will help reduce noxious hydrogen sulfide emissions.

**Offsetting greenhouse gas emissions associated with biofeedstock production.**

Perennial grasses are a potential bioenergy feedstock, and nitrous oxide emissions associated with their production must be balanced by the amount of carbon they sequester in the soil. An ARS researcher in Morris, MN, compared nitrous oxide emission and soil carbon storage between grasses grown with legumes or with nitrogen fertilizer under different management scenarios. Findings indicate that beneficial soil carbon levels increased under perennial grass production but that nitrogen fertilizer management needs to be refined to optimize grass production while minimizing nitrous oxide emissions. This work will help producers, agronomists, and energy industry meet crop production goals while reducing emissions related to nitrogen fertilization.

**Electronic nose sensors can be used to detect odors from biosolids.**

Gas monitoring tools such as electronic nose sensors are a promising approach for applications where rapid and automated detection of specific gases or patterns of gases are required. They can also be used to discriminate between air samples containing complex compound mixtures. However, little information is available on using sensor arrays to monitor the processes involved with the treatment and use of biosolids, which are used as an alternative fertilizer source. ARS scientists in Beltsville, MD, conducted studies to examine the feasibility of using electronic nose sensors to explore their ability to detect key odors and to discriminate between treated biosolids that were stabilized with various amounts of lime. The electronic nose sensors were able to discriminate the different alkaline (e.g., lime) dosages used to stabilize the biosolids. Their results were very similar to results obtained with sophisticated analytical instrumentation, but the analytical instruments could detect the gases at much lower concentrations. These findings can provide important information on the use of commercially available

electronic nose technologies to increase the effectiveness of biosolids treatment programs and help resolve odor complaints when biosolids are applied to agricultural fields.

**Yield predictions vary among potato crop models.**

Crop models are frequently used to predict the impact of climate change on agricultural yield. Several models have been developed for each major crop commodity, but model predictions may vary because each model uses different assumptions. ARS researchers in Beltsville, MD, conducted an international study of crop modeling and included nine potato crop models. They found that simulated tuber yields significantly varied among models, and that this variation increased when the study focused on rain-fed locations when compared to irrigated potato production locations. Increased air temperature was the climate variable with the strongest association to yield variability. Successfully forecasting how changing climates affect crop yields requires understanding why estimates vary, and these findings can help crop modelers, climate change researchers, and agricultural policy planners improve climate impact assessment tools and develop adaptation strategies.

**Positive effects of carbon dioxide on crop growth vary with temperature.**

ARS researchers in Beltsville, MD, conducted an international study using 13 to 26 crop models for wheat, corn, and rice to assess the effects of increasing temperature and carbon dioxide on crop yield. These simulations identified a cutoff point at which the positive effects of increased carbon dioxide concentrations on crop yield could compensate for potentially negative effects of rising temperature on crop yields. The research is useful to climate change researchers who use and interpret crop models and

policy experts who use results from simulation models to adapt agricultural practices to changing climate conditions.

### **Novel microbes lower cost of cellulosic ethanol production.**

Developing cost-effective cellulosic ethanol production is difficult in part because of the expensive cellulolytic enzymes needed to break down biofeedstock before it can be converted into fuel.

Researchers are also studying ways to manage inhibitory compounds that can result from fermentation and slow the conversion of biofeedstock to cellulosic ethanol. ARS scientists in Peoria, IL, worked with partners to develop a new yeast strain with a unique cellulolytic enzyme that efficiently breaks down biofeedstock, shows resistance to inhibitory compounds, and eliminates the need to add other enzymes to the production process. The scientists assessed the efficiency of this yeast strain in converting pretreated rice straw into cellulosic ethanol and obtained a production rate of 36.7 grams per liter in 36 hours with a conversion efficiency of 90.1 percent. This translates into reducing enzyme costs in cellulosic ethanol production by around \$0.35 per gallon. This technology supports the rural economy and is expected to reduce risks and increase profitability in existing industrial biorefineries that produce ethanol and other products.

### **Ethanol from coffee waste.**

The cost-effective production of fuels and chemicals from agricultural residues requires a microorganism that can convert all the available sugars in the biofeedstock. ARS scientists in Peoria, IL, identified a strain of yeast that can convert inulin, a major polysaccharide derived from coffee processing waste, into cellulosic ethanol. Using this yeast provides a new method for disposing of waste

products from coffee processing and furthers the development of environmentally cost-effective and potentially profitable processes for managing agricultural byproducts.

**Converting switchgrass and corn stover sugars into biodiesel and bio-jet fuel without costly enzymes.**

ARS researchers in Peoria, IL, worked with partners to demonstrate the feasibility of directly converting extracted plant sugars into oils that could be used as biodiesel or bio-jet fuel. This new process is suitable for producing a renewable intermediate for biodiesel or bio-jet fuel production. It is cost competitive with petroleum-based oils because sugars are extracted from plants without using enzymes that typically drive up costs in producing sugars from plant fibers. The actual savings of this technology in dollars has not been released but preliminary findings suggest it could reduce cellulosic ethanol production costs by 16 to 20 percent.

**Eliminating sweet sorghum syrup spoilage during long-term storage.**

Because of its rich sugar medium, sweet sorghum syrup is highly susceptible to surface microbial spoilage during storage. This is a major impediment to using sweet sorghum syrup for the commercial, large-scale manufacture of biofuels and bioproducts. ARS scientists at New Orleans, LA, and an industrial collaborator showed that the adding a thin layer of inexpensive soybean, canola, or sunflower oil as a surface sealant allowed sweet sorghum syrup containing 65 percent dissolved solids to be stored for at least 1 year at ambient temperature. Heckemeyer Mill (Sikeston, Missouri) is now using this novel technology to store syrup in 7,500-gallon tanks.

**New method to analyze sorghum wax and commercial waxes.**

Gas chromatography has traditionally been used to analyze wax components, but the high temperatures used in the process can lead to inaccurate results. ARS researchers in Wyndmoor, PA, developed a new high performance liquid chromatography (HPLC) method to quantitatively analyze sorghum wax. This is the first successful HPLC method for waxes and employs evaporative light scattering detection to accurately quantify sorghum wax in sorghum oil, distiller's milo oil, and in sorghum grain processing fractions such as bran and distillers dried grains. It also is very useful in analyzing commercial waxes such as carnauba wax, candelilla wax, sunflower wax, rice bran wax and beeswax. This new HPLC method has the potential to become widely used for commercial wax analysis.

**Improved industrial yeast strains for producing bio-ethanol from biomass-derived sugars.**

Maximizing cellulosic ethanol production rates requires the complete and efficient utilization of all biofeedstock sugars. Although some robust yeasts effectively convert plant sugars in industrial biorefining conditions, their conversion rates can be reduced by inhibitors formed during the production process. After a yeast strain from a Brazilian fuel ethanol production facility was found to tolerate these inhibitors, ARS scientists in Peoria, IL, engineered the yeast to convert plant xylose to ethanol and then identified a strain with excellent performance. They found that when this yeast strain was used to convert hydrolyzed switchgrass into cellulosic ethanol, it produced 30 percent more ethanol than the original parent strain. Using this new strain could reduce production costs for any cellulosic production process using biomass-derived sugars, which will help increase profits.

**Lytic enzymes control bacterial contamination of cellulosic ethanol.**

Lactic acid bacteria frequently contaminate commercial fuel ethanol fermentations and reduces yields and biofuel production profits. ARS scientists in Peoria, IL, and Beltsville, MD, purified four lytic enzymes that possess antibacterial activity and mitigate the effects of contamination in cellulosic ethanol production. Treatments with each enzyme reduced the concentration of lactic acid bacteria by 1000-fold and increased ethanol yield nearly 10-fold in infected fermentations. These findings indicate that lytic enzymes can be used by the fuel/ethanol industry as an alternative to antibiotics for preventing and controlling bacterial contamination during biorefining.

**Determining sweet sorghum quality traits.**

Producers, breeders, and manufacturers need quick and cost-effective methods to measure quality traits in new sweet sorghum feedstocks used for manufacturing biofuels and bioproducts. ARS scientists at New Orleans, LA, developed a multivariate statistical methodology that uses inexpensive fluorescence and light absorption/reflectance observations to predict key sweet sorghum genotype traits. This new technique allows breeders and growers to predict sugar concentrations or selected impurities in juice or bagasse samples. Current advanced statistical pattern-recognition methods were also used with sorghum grain samples to understand the chemical traits responsible for the pest (aphid/worm/bird) resistance. This new technique replaces near-infrared and chromatography techniques and will help breeders and others advance the cost-effective production of cellulosic ethanol using sweet sorghum biofeedstocks.

**Improved recovery of pathogenic *Escherichia coli* from a bioaerosol sampler.**

Airborne pathogens generated during manure management are a potential health risk, but these pathogens are often not recovered from liquid-based bioaerosol samplers. ARS researchers at Kimberly, ID, evaluated the effectiveness of several low-viscosity collection fluids to improve the recovery of viable *E. coli* cells from samplers that monitor pathogen levels. Viable *E. coli* recovery rates ranged from 87 to 98 percent after 90 minutes of operating samplers with peptone or antifoam agents in comparison to lower recoveries using simple buffers or water. The results indicate that using these substances or similar agents will help organisms survive stresses associated the sampling process and improve the accuracy of bioaerosol sampling, which will help researchers more accurately assess the abundance of airborne pathogens that may present a quantifiable risk to human health.

**Creating value-added products from agro-industrial residues.**

Textile, leather, rubber, plastics, and food industries use synthetic dyes such as methylene blue (MB) to color their products. The wastewater generated by these processes commonly contains toxic compounds and/or carcinogens, is highly colored, and is commonly discharged into the environment. This contaminated discharge lowers oxygen levels and reduces light levels in the receiving waters, which leads to reduced photosynthesis in aquatic environments. ARS scientists from Bowling Green, KY, used an acid dissolution-precipitation process to extract silica and residual ash from agro-industrial residues and found the silica and ash provided a low-cost adsorbent for removing MB from aqueous waste streams. These findings can potentially lead to an eco-friendly and sustainable method for transforming agro-industrial wastes into value-added starting materials for different industrial applications, as well as for developing adsorbent materials that can be used to treat chemical pollution.

### **Improved detection and quantification of *E. coli* O157:H7.**

Technology that enables fast and reliable detection and measurement of *E. coli* O157:H7 in food and environmental samples is a critical need for food safety and public health assessments. An ARS scientist from Riverside, CA, and California State Polytechnic University partners used recombinase polymerase amplification (RPA) for the rapid detection of *E. coli* O157 and droplet digital polymerase chain reaction (ddPCR) for accurate *E. coli* O157:H7 measurement. The assays were applied to swine, dairy, beef, and duck manure, and wastewater effluent collected from a dairy wetland over a 12-month period. Quantification by ddPCR was able to distinguish *E. coli* O157:H7 from environmental samples with 75 percent sensitivity and 80 percent specificity. These new methods improve the process of identifying factors linked to the contamination of surface and ground waters used for fresh produce irrigation, which will help producers identify irrigation water that may be contaminated with *E. coli* O157 pathogens, protect fresh produce from pathogens that cause serious foodborne illness, and protect consumers from foodborne illness.

### **How manure-based biochar soil amendments affect microbial communities.**

The agriculture community in the Southeastern Coastal Plains needs strategies for addressing regional soil issues, such as low water holding capacity and low fertility. These soil conditions reduce nutrient retention and soil health, which lead to reduced crop yields. Some biochar soil amendments have been shown to positively affect soil microbes, with a resulting impact of improved soil health and fertility. ARS researchers in Florence, SC, collaborated with the U.S. Environmental Protection Agency to assess how manure-based biochar amendments affected the composition of microbial communities in two typical Coastal Plains soils. They found amendments supported significant shifts in microbial

community composition and that these changes were greater in Norfolk soils than in Coxville soils. Additionally, these microbial community shifts correlated with availability of nutrients such as phosphorus, which increased as a result of the biochar amendment. These results indicate manure-based biochars can improve soil biological properties that support healthier and more fertile soils, which will improve producer profits and agroecosystem sustainability.

### **Liming manure helps control porcine epidemic diarrhea virus.**

The ongoing outbreak of porcine epidemic diarrhea virus (PEDv) costs producers and others up to \$8 billion annually. Managing an outbreak requires effective manure treatment to inactivate the virus. In a series of soil incubations, ARS researchers in Lincoln, NE, evaluated how long PEDv persists during normal soil incubation (the standard manure management practice) and whether quick lime additions to manure storage before soil application could control the virus more effectively. While the standard soil application practice inactivated PEDv within 30 days, liming manure to a pH of 10 before it was applied to soil proved highly effective and inactivated the PEDv immediately. Results from this study are quickly being disseminated through extension communications and other commodity networks, and producers are quickly adopting the practice to help control PEDv outbreaks.

### **Modifying dairy cow diet can reduce methane emissions and potentially increase pathogens in manure.**

Model simulations have indicated that modifying livestock diets to reduce nitrogen excretions can increase enteric emissions of methane, which is a potent greenhouse gas. ARS researchers in Kimberly, ID, and collaborators examined how dietary forage and crude protein content affected enteric methane

emissions, as well as nitrogen and pathogen (e.g., *Escherichia coli* O157:H7 and *Listeria monocytogenes*) excretions from lactating dairy cows. They found that reducing dietary forage reduced methane emissions, and that reducing crude protein content reduced total manure nitrogen excretions in cows fed alfalfa hay-based diets. However, *Listeria* fecal concentrations were higher when cows consumed low-protein diets. These findings indicate that livestock diets with reduced forage and crude protein can be used to reduce methane emissions and nitrogen excretions from dairy cows, but these diets can also increase *Listeria* output. These results will improve farm system models for predicting the effects of diet on methane emissions and nitrogen budgets, which can help producers manage greenhouse gas emissions.

**A patented microbial method for reducing nitrous oxide emissions associated with nitrogen fertilizer.**

Nitrous oxide losses associated with the use of nitrogen fertilizers is a problem because the nitrogen cannot be used by crops and nitrous oxide is a potent greenhouse gas. Over the past few decades, nitrous oxide emissions have increased worldwide for several reasons, including increases in the land area being used for cultivation, excessive nitrogen fertilizer application, and increased livestock production. Ongoing research by ARS scientists in Auburn, AL, has demonstrated some soil microorganisms can promote plant growth, and that these inoculants could be used to reduce nitrous oxide emissions from nitrogen fertilizer applications. Results indicate that applying these soil microorganisms with certain fertilizers can reduce nitrous oxide emissions. These findings provided the basis for a new patent and have resulted in the development of new management tools to reduce nitrous oxide emissions from agricultural production.

**Development and optimization of nutrient conservation practices to prevent the loss of excess phosphorus to the environment.**

Producers currently assess crop response to growing conditions by using soil testing and fertility recommendations. ARS researchers in Beltsville, MD, conducted a study using a newly-developed X-ray fluorescence method to make instantaneous measurements of water content, phosphorus, and other mineral nutrients in leaves of corn seedlings. The scattered radiation intensities from characteristic regions of the fluorescence spectra for seedling leaves allow on-the-go measurement and correction for canopy water and nutrient status in the plant. This method will help crop specialists and producers develop and optimize nutrient conservation practices and prevent the loss of excess phosphorus to the environment. Results from this work can help organic farmers, educators, NRCS and Extension nutrient managers, and policymakers develop new strategies for assessing plant responses to local growing conditions.

**Quantification of health risk from dairy manure irrigation.**

Applying liquid dairy manure to fields through spray irrigation to provide crop nutrients can reduce manure-hauling costs and increase application scheduling flexibility during a growing season. However, by using this approach, manure pathogens might be transported downwind and become a potential health hazard for people and livestock. ARS researchers at Marshfield, WI, found that airborne manure microorganisms decreased with distance downwind from an irrigated site, but could still be detected 700 feet away. They calculated that each irrigation event could transport pathogens 500 feet downwind and that people exposed to the airborne pathogens would have only a very small risk of becoming ill as a result of exposure, comparable to risk levels that have been assessed as acceptable for drinking

municipal water or swimming at a beach. The study is the first to use measured concentrations of airborne pathogens during manure irrigation to estimate human health risk from spray irrigation, and can be used by policymakers and public health agencies to establish safe setback distances.

**Determination of trial length swine odor reduction studies.**

People who live near swine production facilities are often affected by noxious odors from the facilities. One of the problems with designing animal trials to assess odor-reduction strategies is that they are often hampered by uncertainty about optimal scheduling for measuring odor compounds. ARS researchers in Ames, IA, investigated the length of time needed to conduct a valid feeding trial for evaluating odor emissions. They found chemical compounds making up odors did not stabilize until 5 weeks into the animal trial, which indicates that experiments to determine the effectiveness of odor-reduction strategies should be performed for at least 5 weeks. Previous odor-reduction experiments reported in the scientific literature were performed for as little as 1 week. This provides valuable information for the design of future experiments on odor reduction, including the need for extended trials, which will require additional time and funding.

**First report of avian influenza virus in groundwater.**

During the 2015 outbreak of avian influenza virus (HPAI) on Midwest poultry farms, heavy spring rains and manure spreading created conditions where groundwater was polluted with the virus in some areas. However, it was not known if HPAI could spread through groundwater. ARS researchers at Marshfield, WI, sampled 20 wells on 13 poultry farms in Iowa and Wisconsin affected by the outbreak and found that 3 wells were positive for a gene indicating the presence of influenza A virus. One well was also

positive for a gene unique to the HPAI outbreak strain. Water from seven wells was positive for a parvovirus unique to poultry, which demonstrated a link between contaminated manure and groundwater. This was the first report of avian influenza virus in groundwater, and shows groundwater could be an overlooked route for transmission. This work will help policymakers and public officials establish practices for safe water supplies on poultry operations.

**A prototype implement for applying poultry litter in shallow trenches.**

Poultry litter is a solid material that is a mixture of chicken manure and bedding material. This litter is commonly used as a fertilizer on pastures and cropland and is typically land-applied by broadcasting the litter on the soil surface. Rainfall runoff from fields where poultry litter has been applied may carry phosphorus and nitrogen nutrients from the soil into streams, lakes, and other water bodies. This nutrient-rich runoff contributes to eutrophication and the growth of toxic algae in surface waters. Liquid manure from dairy cows, hogs, and laying hens is often land-applied by injecting it beneath the soil surface, a technique that helps control odor and reduce nutrient losses. An implement for subsurface application of solid manure, such as poultry litter, has not been available, so a prototype implement for applying poultry litter in shallow trenches and covering the litter with soil was developed at by ARS scientists in Auburn, AL. The implement is equipped with four trenching devices and applies litter in four subsurface bands simultaneously. The implement works well for side-dressing litter to row crops and for subsurface band application of litter in pastures and could provide producers with a more environmentally sustainable process for fertilizing their fields with poultry litter.

**Tannins in dairy cow diets reduce greenhouse gas emissions.**

Dairy cows contribute to greenhouse gas emissions and global climate change directly via enteric methane emissions and indirectly via nitrous oxide and ammonia emissions from their manure. ARS researchers at Madison, WI, conducted a pilot project to see if they could reduce cow gas emissions over extended periods (periods lasting over a month) by adding condensed tannins extracted from Quebracho trees to dairy cow diets. Tannins are compounds naturally present in tree leaves, and Quebracho trees are found in South America. While the pilot project results were not statistically significant because of the small sample size and wide responses, the scientists found that overall, adding these tannins to livestock diets lowered methane emissions by 33 percent, nitrous oxide emissions by 70 percent, and ammonia emissions by 23 percent, and did not affect milk production. While these results warrant further study, they suggest that dairy producers may be able to use relatively low amounts of tannins to reduce cow gas emissions throughout lactation, which could provide a potential long-term strategy to significantly improve the environmental sustainability of milk production.

**Phosphorus model improves restoration efforts for the Chesapeake Bay.**

Water quality restoration efforts for the Chesapeake Bay are focused on reducing phosphorus loss from farm fields. The Chesapeake Bay Watershed Model has been used for two decades to simulate hydrology and phosphorus loss and to support water quality policy development, but it has a limited capacity for simulating phosphorus loss from fields. ARS researchers at Madison, WI, and collaborators used the ARS Annual P Loss Estimator (APLE) computer model for field phosphorus loss as an alternative to the Bay Model approach, and found that APLE improved Bay Model prediction performance at 75 percent of river monitoring stations. Incorporating APLE into the Bay Model will

improve the Bay Model's ability to simulate phosphorus loss and the impact of farm field management on Chesapeake Bay water quality.

**Spatial emission characteristics of beef feedlot pens.**

An ARS researcher at Clay Center, NE, completed a laboratory study that detailed how moisture content and temperature affected odor emissions from a range of sites within a feedlot pen. The study demonstrated that the majority of odor emissions occur near the base of a mound of manure and that little odor is emitted when soil temperatures are below 25 degrees Celsius or when manure is air dried. Procedures were developed to conduct these studies in an environmentally controlled chamber to more closely represent field conditions. These findings will help feedlot producers develop strategies for managing noxious odor emissions.

**Detection limits are established for waterborne pathogens.**

Scientists use a molecular biology analysis method called Quantitative Polymerase Chain Reaction (qPCR)—a precise, efficient and rapid method for analyzing a range of genetic materials—to detect pathogenic microorganisms in environmental water samples. However, detection limits are not commonly reported. ARS researchers at Marshfield, WI, developed an efficient approach to determine these detection limits by measuring levels of specific genetic materials for *Salmonella*, adenovirus, and enterovirus. This new detection limit determination approach gives scientists a critical tool for comparing detection methods, designing effective studies for identifying potentially pathogenic microbes, and helping data interpretation, all of which will help resource managers safeguard and improve water supplies.

**Application rate and frequency needed to reduce ammonia in deep-bedded pack barns.**

Ammonia emissions in livestock production facilities create noxious odors. ARS researchers at Clay Center, NE, determined that weekly additions of 5-10 percent alum in deep-bedded pack barns- which have a bedding pack of straw, hay, sawdust or well-chipped wood shavings- effectively lowered ammonia concentration for up to 49 days. If applied only once, ammonia concentration could be lowered for up to 21 days if 10 percent alum was used. Recommendations have been developed to help producers manage livestock facilities to minimize their impact on air quality outside the barn.

**Understanding effects of aged litter materials on chemicals in dust particles at poultry production facilities.**

In poultry houses, toxic gas emissions can adversely affect the health, performance, and welfare of animals and human operators. Inorganic ions such as ammonium, nitrate, and sulfate and their emissions can also be major sources of environmental pollution, and particulate matter (PM) acts as a carrier for odorous compounds. PM is generated from feed, animal manure, and the birds themselves. ARS scientists from Bowling Green, KY, examined how reusing aged litter affects air quality in poultry housing, and found that inorganic ions in PM increased with successive flocks and were highly concentrated in larger PM. Understanding how management practices affect poultry air emissions will lead to innovative best management practices that safeguard the health and welfare of the animals and the poultry operators, and reduce the environmental impact of potential air pollutants. This information can also help optimize estimates of inventory and emission factors for these environmental pollutants.

**Gypsum applications reduce phosphorus losses from poultry litter applications.**

There are growing concerns regarding the fate of nutrients, especially phosphorus, from land application of animal waste. One approach to reduce runoff losses of phosphorus is to treat manure or the soil receiving manure with chemical amendments such as gypsum. ARS scientists conducted a simulation study to see if flue gas desulfurization (FGD) gypsum applications reduced phosphorus loads in Coastal Plains soil runoff. They found that applying 8.9 Mg ha<sup>-1</sup> FGD gypsum reduced soluble reactive phosphorus load by 51 percent and that measurements of heavy metals in runoff were all found to be either below detection limits or similar to levels found with no gypsum application. The results indicate that use of FGD gypsum on pastures receiving poultry litter in the Coastal Plains would be an effective method of reducing reactive phosphorus losses to the environment and controlling agricultural pollutants. Based on this work, USDA's National Resources Conservation Service has adopted the use of gypsum with manure application as an NRCS National Standard.

**Alum additions to poultry litter precipitate organic phosphorus.**

One of the biggest environmental problems associated with the poultry industry is non-point source phosphorus pollution from poultry litter applications. ARS scientists at Fayetteville, AR, found that adding alum to poultry litter greatly reduces both phosphorus runoff and phosphorus leaching. Last year, these ARS scientists found that phosphorus concentrations in soils fertilized with alum-treated litter were much higher when analyzed by inductively coupled argon plasma emission spectrometry (ICAP) than by colorimetry, indicating the formation of an organic phosphorus mineral, such as aluminum phytate. Formation of this organic form of the mineral would reduce phosphorus transport. It might also change the way soil samples are analyzed by soil-testing laboratories, since using an ICAP

may overestimate the amount of available phosphorus. ARS scientists in University Park, Pennsylvania, and colleagues are using nuclear magnetic resonance (NMR) and gas chromatography (GC) mass spectrometry to conduct follow up studies for determining the composition of this organic phosphate mineral, which could help refine soil-testing strategies and results.

**Measuring odor emissions from modern dairy and swine facilities.**

As the urban-rural interface grows, there are increasing conflicts between agricultural and non-agricultural entities regarding odors from animal feeding operations. Odor and odor-causing chemical emissions from large animal buildings are difficult to measure because they vary with time and weather. In this supplemental project to the National Air Emissions Monitoring Study (NAEMS), ARS scientists worked with colleagues from Iowa State University, Purdue University, University of Minnesota, and West Texas A&M University to continuously measure odor and odor-causing chemical emissions from two dairy facilities and two swine facilities over 2 years. Study results provide producers and regulators with odor emission estimates from animal buildings that can be used to help optimize building siting and assess impacts to downwind receptors.

**Diet composition affects manure composition and methane generation in finishing pigs.**

Alternative feed ingredients with higher fiber content can have dramatic effects on the energy and nutrient digestion in the growing pig. These changes can affect manure composition and characteristics such as dry matter levels and levels of carbon, nitrogen, and sulfur. ARS researchers in Ames, IA, demonstrated pigs that consumed higher fiber diets produce manure characterized by higher methane production rates and biochemical methane potential compared to pigs fed diets with lower levels of

dietary fiber. These findings may help producers develop strategies for controlling methane emissions from production facilities.

### **Understanding urea transformations in soil.**

Urea is a common component of nitrogen fertilizer, and researching urea transformations in soil is important for evaluating urea's potential for increasing eutrophication risks to nearby streams or estuaries. ARS researchers in Beltsville, MD, completed a field study that showed the conversion of urea to ammonium-nitrogen was eight times faster in the surface soil than in the subsoils of three different important areas: the grain-production area, an edge-of-field grass border, and a nearby perennial riparian zone. These results suggest that organic-matter rich riparian-zone soils may be valuable in mitigating losses of unhydrolyzed urea from neighboring fields. This research provides valuable information to scientists, nutrient managers, and policymakers for understanding the likely benefits that neighboring non-agricultural ecosystems can provide for reducing the potential loss of free urea from nitrogen fertilizers to nearby bodies of water.

### **Optimizing conditions for beef deep-bedded manure packs.**

An ARS researcher at Clay Center, NE, conducted laboratory experiments to evaluate the use of mixtures of pine chip and corn stover bedding materials in deep-bedded barns. Mixtures containing 30-40 percent pine chips were found to be the ideal combination to reduce ammonia and total reduced sulfide emission. Gas concentrations increased as the packs aged, suggesting that frequent cleaning of the facilities would improve air quality in the barn regardless of which bedding material is used. This information can help livestock producers optimize animal housing conditions in barns.

**Cattle feed supplements may increase sulfur gas emissions.**

Over the past decade, beef cattle feedlot operators have included supplements of dried distiller's grains with solubles (DDGS), a corn ethanol coproduct, in standard feedlot rations. While cattle production remained unaffected, there was little information on how DDGS affected the composition of manure, including gas emissions, nutrient composition, and potential pathogen content. In three beef cattle feedlot studies, ARS researchers in Lincoln, Nebraska, and Clay Center, NE, measured and compared sulfur gas emissions from cattle feedlot manures and soils where cattle consumed older corn-based diets or newer diets containing DDGS. Sulfur gas emissions from DDGS manures and soils were two- to fivefold greater, with fresh manure being the strongest source. Producers can use these findings to mitigate sulfur emissions from manure by reducing sulfuric acid used during ethanol production or by more intensive manure management in cattle feedlot pens.

**Hepatitis E virus from swine is common in Iowa surface water.**

The gastrointestinal Hepatitis E virus (HEV) is common in swine herds, has been detected in swine manure lagoons, and can be transmitted between people, swine, and wildlife such as deer. Information is needed about HEV migration from farms and how it survives in the environment. ARS researchers at Marshfield, WI, found that 45 percent of water samples from the South Fork Iowa River basin in Iowa were positive for HEV, and that HEV detection in water samples increased from 20 percent before manure application to 80 percent after application. Swine manure samples from two farms and deer fecal samples in the basin were all positive for HEV, and HEV in river water, swine manure, and deer feces were genetically identical. This research establishes a basis for improving the assessment of pathogen health risks for people and livestock in the region.

### **Improved measurements of nitrous oxide emissions from feedyards.**

Nitrous oxide is a potent greenhouse gas that contributes to global warming. Nitrous oxide emissions from beef feedyards are difficult to accurately measure and have been shown to vary over a wide range because of different feedyard management practices, weather conditions, and challenges with measurement methods. ARS researchers in Bushland, TX, and Texas A&M AgriLife Research collaborators identified discrepancies in emissions measurements and factors related to nitrous oxide production and found that typical soil measurement methods greatly underestimated manure emissions and didn't capture variability within cattle pens. This research shows that feedyard emissions are highly variable and refined techniques are needed to accurately quantify feedyard nitrous oxide losses. Producers and resource managers can use this information to improve management of nitrous oxide emissions from livestock production facilities.

### **Simulation shows effective manure application strategies for reducing phosphorus runoff.**

Phosphorus loss from farm fields pollutes local waters, and spreading dairy manure in winter or just before large storms can increase the risk of loss. Using the SurPhos computer model and 108 site-years of runoff data, ARS researchers at Madison, WI, showed that phosphorus loss was 3-7 times lower when manure is spread on frozen ground on low-runoff fields instead of on frozen ground on high-runoff fields. Additionally, spreading manure outside of winter reduced phosphorus loss by 3-4 times compared to winter spreading. In contrast, delaying manure application when precipitation is predicted increased the likelihood of runoff and reduced phosphorus loss by only 6-14 percent. These results indicate that spreading manure on low-runoff fields or outside the winter period reduces phosphorus loss

more effectively than timing manure applications around precipitation events. This study helps producers and policymakers determine optimal times for spreading manure to minimize phosphorus loss to the environment.

**Understanding nutrient contributions of cover crop residues and animal manure.**

Cover crop residues and animal manure are critical to improving crop use of organic and inorganic sources of nitrogen. ARS researchers in Beltsville, MD, completed a field study that showed nitrogen uptake by corn tended to be greatest with hairy vetch residue compared to rye cover crops, and was greater with broadcast or subsurface band applications of poultry litter. These findings provide valuable data and information that nutrient managers, producers, and policymakers can use to develop and mandate conservation plans for reducing nitrogen delivery to nearby aquatic ecosystems in the mid-Atlantic region.

**An early-warning system for detecting leakage from wastewater holding ponds.**

Leaks from manure storage ponds and other wastewater ponds can contaminate nearby surface and groundwater sources. Resistivity array technology, which uses electrical currents to assess subsurface conditions, improves the detection of leaks from wastewater holding ponds. The technology provides greater sensitivity to subsurface conditions, improves the detection of leaks in saturated and non-saturated zones, facilitates continuous monitoring, can monitor much larger surface areas, and can be designed to send alerts when leaks are detected. ARS researchers at Clay Center, NE, developed a protocol that automatically calibrates resistivity array technology data analysis to site-specific geology and that uses a series of steps to produce a graphical output for easy interpretation. The sensitivity of

these steps can be adjusted by the user for additional in-depth analysis. This tool can be used to help producers and resource managers monitor the safety of wastewater holding ponds and alert them when leakage is detected, which can help prevent and/or mitigate hazardous wastewater spills into nearby environments.

### **Detection of perfluoroalkyl substances in municipal biosolids.**

Amending agricultural soils with biosolids has numerous benefits, including nutrient addition, soil structure improvement, and reuse of a waste that encourages sustainability. Perfluoroalkyl (PFAS) compounds are widely used industrial products released in large quantities to wastewater treatment plants, where they are partially degraded in the wastewater treatment process. After treatment, the PFAS metabolites then migrate almost entirely into biosolids, where they exist as smaller molecular weight forms that are of toxicological concern. ARS scientists measured the concentrations of 22 likely PFAS compounds in biosolids to determine if levels changed over a 9-year time period (2005 to 2013). Seven compounds were routinely found above detectable levels and the three top compounds were measured in the mid-20 ppb concentrations. None of the measured compounds showed any meaningful increases or decreases over the 2005-2013 sample period, despite restrictions that had been imposed as early as 2000 to limit their production. This information is useful to waste treatment facility managers so that they can improve treatment designs to reduce release of PFAS compounds.

### **Finding genetic resistance in cattle to poisoning by toxic grazing plants.**

Cattle grazing on western U.S. rangelands are at risk of grazing on larkspur and other neurotoxic rangeland plants. ARS scientists from Logan, Utah, and Clay Center, NE, conducted DNA testing to

identify Angus bull and steer genes that convey resistance to larkspur toxins and then selected Angus bulls expressing these genes for progeny testing. This information will benefit ranchers in regions where larkspur and other neurotoxic plants infest rangelands and will help producers reduce cattle losses by making genetic-based grazing decisions and by increasing livestock holdings with heifers and bulls that exhibit resistance.

### **Innovative approaches for remotely monitoring land surface conditions.**

Better remote-sensing methodologies and data acquisition technologies are needed to accurately assess and map rangeland vegetation and monitor rangeland health. ARS scientists compared actual ground-based phenology data with canopy greenness data remotely collected by tower cameras (i.e., phenocams), unmanned aerial vehicle (UAV) based digital imagery, and satellite sensors. Remotely collected information on canopy greenness is useful for estimating plant phenology and production, and results demonstrated that inexpensive phenocams provide valuable data in near real-time. An ARS scientist in Las Cruces, NM, was invited to two workshops hosted by the National Coordinating Office of the National Phenology Network as part of an effort to integrate phenological observations collected at different scales. These efforts contribute to the ongoing development of an LTAR cross-site multi-scale phenology data network. Land managers will benefit from technologies that gather landscape information more quickly and accurately.

### **Holistic grazing system increases soil carbon and nitrogen.**

ARS scientists in Reno, NV, collaborated with a range consultant and completed research on the effects of both traditional and holistic grazing management systems on soil properties in New Mexico.

Traditional grazing, as practiced in this region, is typically year-round with a stocking rate of one cow per 56 acres. The holistic system requires the land be separated into more pastures, because cattle graze each pasture for only 3 to 5 days and then are rotated to another pasture while the grazed pasture is rested for 100 days. Under the holistic management system, stocking rate was increased to one cow per 35 acres. The scientists found that even with the increased stocking rate, the rangelands managed using holistic principles had significantly greater total soil nitrogen and total soil carbon than traditionally grazed rangelands, with less proportion of bare ground and increased forage production, which resulted in the greater stocking capacity. These results indicate that a more holistic approach to grazing management can improve rangeland ecosystem health and environmental sustainability.

**Fall oats improve dairy production sustainability.**

North-central U.S. dairy producers often rely on stored forages to maintain livestock through the winter. Fall-grown oat is an excellent forage candidate because it is a late-season crop with good yield potential, facilitates the application of manure soil amendments during the summer, and helps reduce nitrogen losses to the environment. ARS researchers at Marshfield, WI, found that using nitrogen fertilizers increased fall-seeded oat yields for stored feed by 50 percent or more, that dairy manure applied in summer provided adequate nitrogen, and that oats aggressively take up soil nitrogen. They also determined that heifers managed in central Wisconsin should begin grazing fall-seeded oats in late September because waiting until mid-October consistently resulted in reduced heifer growth, particularly if rapidly maturing oat types were used. This improved fall-oat management information provides dairy producers with information they can use to produce quality animal feed (stored or grazed) and to reduce the environmental risk of nitrogen leaching to groundwater.

**Tools and techniques for multi-scale inventory, monitoring, and assessment.**

Land managers and public land agencies need standardized approaches for monitoring, collecting, and sharing rangeland data to ensure that these efforts generate comparable data across sites. ARS scientists in Las Cruces, NM, led and supported the implementation of core monitoring indicators and methods and scalable sampling designs within the Bureau of Land Management (BLM's) Assessment, Inventory, and Monitoring (AIM) program (including BLM's national guidance and local support for monitoring Greater Sage-grouse habitat) and integration of BLM's monitoring efforts with the existing USDA Natural Resources Conservation Service (NRCS) and Forest Service (FS) monitoring programs. They also led the development of novel techniques for analyzing rangeland monitoring data relative to land potential to produce results that directly support management decision making. The resulting inventory, monitoring and assessment techniques, tools, and resources are available at [www.landscapetoolbox.org](http://www.landscapetoolbox.org) and provide managers and policymakers with information for managing resources at local to continental scales over millions of acres of rangelands.

**Discovery of novel plant endophytes for improved stress tolerance.**

Endophytes are microorganisms that live symbiotically within plants and may improve plant tolerance to abiotic and biotic stresses. ARS researchers in Corvallis, OR, isolated and identified 111 fungal endophytes in 39 genera and 133 different bacterial endophytes in 37 different genera/species, of which 94 were unique isolates. The endophytes were collected from eight different grass species growing in saline environments and sandy soils along the Oregon coast. Fourteen of the bacterial isolates possessed an enzyme associated with improved plant growth under stress. These newly discovered endophytes

have the potential to improve the health and productivity of grasses and other crop species grown in marginal or stressful conditions.

### **Ecohydrologic framework for Ecological Site Descriptions.**

Ecological sites and their descriptions (ESDs) are the primary bases by which rangeland management agencies evaluate ecosystem health, develop management objectives, target conservation practices, and communicate regarding ecosystem responses to management. However, ESDs seldom include ecohydrologic relationships that strongly regulate overall ecosystem health and responses to disturbances and management. ARS scientists in Boise, ID, in cooperation with other ARS scientists and Natural Resources Conservation Service personnel, developed a framework and methodology for integrating key ecohydrologic data and relationships within the ESD structure. The framework includes applying the Rangeland Hydrology and Erosion Model (RHEM) to the development and enhancement of ESDs. The integration of this new technology and framework on ecohydrologic relations expands the ecological foundation of the overall ESD concept for management of U.S. rangelands while improving communication between private land owners and Federal land managers across multiple rangeland management disciplines.

### **Risk assessment tool for landscape management.**

Rangelands are vulnerable to soil erosion, runoff, and other damaging environmental processes, and prediction technologies are critical for managing rangeland resources. ARS scientists in Tucson, AZ, developed the Rangeland Hydrology and Erosion Model (RHEM) tool to evaluate and illustrate how different rangeland conditions can affect the risk of excessive rangeland runoff and soil erosion. Users

can program this Web-based tool to run alternative scenarios for a particular rangeland site, including a user-defined “baseline” scenario, optimal scenarios, or alternative scenarios. The program uses the baseline scenario for a specific site to project low, medium, high, and very high yearly erosion rates and then produces comparable estimates for other scenarios. This tool will greatly facilitate the development of formal Ecological Site Descriptions used by the Natural Resources Conservation Service, Forest Service, and Bureau of Land Management to characterize the hydrologic and vegetation functions of land resources, particularly for grazing lands.

**Golf course putting greens require fewer inputs.**

Because of increasing water restrictions, pesticide use concerns, and economic constraints, golf course managers are reducing their use of fertilizer, water, and labor. Warm-season (C4) grasses use less water, are less vulnerable to summer diseases, and are more tolerant of summer heat, and could be a viable turf alternative for golf course putting greens. ARS scientists and partners conducted a study at 11 locations across the southern United States to evaluate three warm-season grass species (bermudagrass, zoysia, and seashore paspalum) for persistence, winter tolerance, disease incidence, and playing surface quality. They found several bermudagrass varieties displayed these characteristics and may be useful on golf course putting greens. The seashore paspalum only performed well in the southern locations and the zoysia did not display the desired characteristics. Landscape managers can use these findings to develop golf greens that have a lower environmental impact.

**Successful establishment of desirable forage species following cheatgrass weed control.**

Cheatgrass (*Bromus tectorum*) invasion has drastically altered native plant communities throughout the western U.S. rangelands. Establishing long-lived perennial grasses following herbicide treatment is key to maintaining the suppression of cheatgrass and allowing plant succession to occur. ARS scientists in Reno, NV, implemented study plots in northern Nevada to test various herbicides for controlling cheatgrass and establishing desirable plant species for wildlife and grazing. Herbicide applications reduced cheatgrass densities from an average of 210.6/m<sup>2</sup> down to 7.2/m<sup>2</sup>. Drill seeding was used to supplement residual perennial grasses with additional desirable species. As a result, perennial grass densities increased from 0.6/m<sup>2</sup> to 10.7/m<sup>2</sup>. Results show that cheatgrass control using appropriate herbicides is a critical step in the successful rehabilitation of rangelands in the Great Basin. These findings indicate that rangeland managers in the region who include herbicide treatments will have greater rehabilitation success and potentially save millions of dollars by minimizing unsuccessful restoration efforts.

**Global warming increases cheatgrass invasion in Great Plains rangeland.**

Cheatgrass is one of the most problematic invasive plant species in U.S. rangelands, but has historically had relatively less impact on Great Plains ecosystems. ARS researchers in Fort Collins, Colorado, and Beltsville, MD, worked with University of Wyoming collaborators and discovered that experimental warming increases cheatgrass biomass and seed production by 400 percent in mixed-grass rangeland near Cheyenne, WY. In contrast, elevated carbon dioxide levels had little effect on cheatgrass, probably due to nitrogen limitation. These findings suggest that producers and public land managers in the

mixed-grass prairie, the largest remaining grassland in North America, may need to manage cheatgrass more aggressively in coming decades.

### **Soil erosion threatens rangeland sustainability.**

Concentrated flow erosion processes are different from splash and sheet flow processes because of their enhanced ability to mobilize and transport large amounts of soil, water, and dissolved elements offsite, and negatively impact soil health and site sustainability. A team of ARS scientists in Reno, NV, worked with ARS scientists in Tucson, AZ, and Boise, ID, to develop a new risk assessment tool that uses information about a site's historic plant community to assess site sustainability and potential soil loss from concentrated flow erosion. With this new information and utilizing the Rangeland Hydrology and Erosion Model (RHEM), managers have a simple and accurate tool to rapidly assess and establish priorities for determining which areas need conservation.

### **Grazing management strategies to prevent wildfires in western rangelands.**

Exotic annual grasses such as cheatgrass now grow on nearly 100 million acres of western U.S. rangeland. Dry cheatgrass stands increase the amount of highly flammable fine fuels in infested areas, which in turn increases the frequency and size of wildfires. These wildfires threaten human safety, reduce livestock forage, and degrade wildlife habitat. They also create conditions that support cheatgrass expansion, which crowds out native plants in rangeland ecosystems. Cheatgrass mitigation efforts have focused on reseeding or replanting native plants after a wildfire, but these efforts have only had limited success. ARS scientists in Burns, OR, have developed management strategies to effectively reduce fine fuel loads which in turn reduces wild fire frequency and heat intensity. They developed a

model and research framework for using pre-fire fuel-load management (including livestock grazing) to reduce the loss of desired native plants during wildfires and reduce reliance on post-fire seeding practices that are often ineffective. These strategies provide ways to preserve native plant ecosystems and reduce losses when fires do occur, and to reduce the likelihood of cheatgrass invasion. This work provides ranchers and public land managers with strategies for preemptive fuels management, and serves as a framework for identifying key research questions to guide future studies.

**‘Trailhead II’, an improved native basin wild rye.**

Many areas of the Western United States have been severely degraded by human disturbance, wildfires, and the invasion of weedy annual plant species such as cheatgrass and medusahead rye. ARS scientists at Logan, UT, developed and released ‘Trailhead II’, a wildrye cultivar that stands from 3 to 6 feet tall and is ideal for providing wind protection in winter calving pastures. Mature plants are also nutritious (7-8 percent protein) and withstand heavy grazing and trampling in its dormant state. Because it is a drought-tolerant bunch type grass with a fibrous root system and adequate seedling vigor in arid regions, it is well adapted for stabilizing disturbed soils. These characteristics, plus its rapid emergence and overall potential for rapid establishment, make ‘Trailhead II’ a desirable plant material for reclamation, conservation, and re-vegetation plantings in the Intermountain West and Northern Great Plains areas of the United States.

**‘Charleston Peak’, a native wheatgrass with improved rangeland stand establishment characteristics.**

Vast areas of semi-arid rangelands in the Western United States, particularly in the Great Basin, are severely disturbed, frequently burned, increasingly eroded, and subsequently infested with troublesome weeds such as cheatgrass and medusahead rye. Compared to invasive weeds, native grasses that grow in these arid regions are more difficult to establish, less productive and persistent, and less tolerant of grazing during periods of severe water stress. Slender wheatgrass is a perennial native plant that is self-pollinating, short-lived, and that colonizes degraded landscapes. Because of its underground plant stem, ARS scientists at Logan, Utah, released ‘Charleston Peak’ slender wheatgrass germplasm as an improved alternative to current slender wheatgrass cultivars for erosion control and re-vegetation plantings on arid and semi-arid rangelands for the U.S. Great Basin and Intermountain Regions. ‘Charleston Peak’ germplasm is adapted to elevations ranging from 4,500 to 12,000 feet, prefers loams and sandy loams, and can tolerate high soil salinity ranges. The release of this cultivar fills a critical need for competitive, persistent, native grasses with increased seed yields that can be seeded and easily established on disturbed harsh range sites.

**Northern mixed-grass prairie can slowly recover from heavy grazing.**

Sustainable rangeland management hinges on a solid understanding of how grazing management decisions affect short- and long-term plant community response. For many rangelands, current conceptual models suggest that heavy grazing can cause irreversible shifts in vegetation composition, but few studies have tested this idea. ARS researchers at Fort Collins, Colorado, and Cheyenne, Wyoming, found that 33 years of heavy grazing caused a decline in the cover of desirable cool-season

grasses while the cover of warm-season grasses increased. But contrary to expectations, reversing management from heavy grazing to light or no grazing allowed cool-season grasses to recover, indicating that northern mixed-grass prairie is more resilient to grazing than current models predict. The results suggest that it takes more than a decade of light grazing for a heavily grazed plant community to revert to light-grazing conditions, and this recovery timeline is economically burdensome for most producers. These findings indicate that long-term data add critical rate-of-change information to conceptual models, and researchers can use this information to provide producers with improved semiarid rangelands management planning tools.

**Effective new diagnostic tool for root-knot nematodes.**

Some nematodes such as root-knot nematodes infect plants through the roots and cause billions of dollars in crop losses worldwide each year, but identifying some of these nematodes in the soil can be nearly impossible. Carrots infected with root-knot nematodes develop deformed roots that have reduced abilities to take up nutrients. An ARS scientist at Beltsville, MD, in collaboration with scientists from Denmark, developed a new DNA test to detect the northern root knot nematode. This new diagnostic test is very sensitive, highly specific, and can detect this species directly in the soil. This research will be used by researchers and agronomists to accurately identify infested fields and determine infestation levels, which will help growers to make informed management decisions before carrot cultivation.

**Increasing species richness improves pasture yield and carbon sequestration.**

Pasture management needs to be optimized to increase forage production and provide ecosystem services such as increased soil carbon sequestration. ARS scientists in University Park, PA, conducted a 9-year study and found that forage yield from a five-species mixture was 31 percent greater than forage yield from a two-species mixture. Yield benefits from the five-species mixture were greatest in years with high rainfall and were greater than average in the last 2 years of the study, suggesting that the effects were long lived. The five-species mixture also sequestered three times as much soil organic carbon as the two-species mixture. This study showed that increasing the number of sown species can have multiple, long-term benefits for temperate pastures.

**Germplasm and molecular markers for improving alfalfa drought tolerance.**

Enhancing alfalfa drought resistance and water-use efficiency will help plant breeders meet the challenges of finite available water resources. An ARS researcher in Prosser, WA, conducted greenhouse and field studies and identified 27 alfalfa accessions with higher drought-resistance levels than the current drought-resistant alfalfa control. A laboratory study resulted in the identification of 20 genetic markers associated with drought resistance and 15 genetic markers associated with relative water content. Genetic markers associated with salt tolerance were also identified and located on three chromosomes. These markers are potentially useful in marker-assisted breeding of new alfalfa varieties with drought resistance and enhanced water-use efficiency.

**Prediction of climate-driven vegetation state changes.**

Climate changes are expected to affect future precipitation levels in arid regions. ARS scientists in Las Cruces, NM, used long-term experimental rangeland data that included drought and wet periods to predict the response of perennial grasses on sites dominated by different mesquite, creosotebush, and tarbush shrubs under a future drier or wetter climate. They found shrub production was linearly related to rainfall during drought and no-trend years. However, during an extended wet period, a nonlinear increase in grass production occurred. The fastest grass response occurred in mesquite-dominated sites, intermediate responses in tarbush-dominated sites, and slowest responses in creosote-dominated sites. These site-specific responses were related to soil texture and plant available water. These findings are being used to enhance models for predicting shrub-to-grassland ecosystem changes under alternative land use-climate scenarios. The data and models provide information that will help managers better maintain and utilize their grazing lands.

**Bacterial stem blight disease of alfalfa is an increasing threat to forage production.**

In the past several years, late spring and early fall frosts have damaged alfalfa fields and reduced producer profits. In some locations, increased sensitivity to frost was associated with herbicide application. ARS researchers in Saint Paul, MN, found that damaged alfalfa was infected by the bacterial stem blight pathogen, which has the ability to increase the range of temperatures at which frost damage will occur. When they sequenced the genome of the pathogen and compared it to other bacterial genomes, they found it is closely related to bacteria infecting pears and beets. They developed methods for identifying resistant alfalfa plants and used them to identify alfalfa cultivars with resistance. Plant breeders will be able to use these methods, the bacterial isolates, and associated plant materials for

developing alfalfa cultivars with high levels of bacterial stem blight resistance, which will support integrated disease management and sustainable forage production.

**Sterile, perennial sorghum species hybrid released.**

Cold-tolerant and noninvasive perennial forage sorghums are needed for increased hay production. ARS researchers at College Station, TX, and Texas A&M University scientists collected and evaluated a naturally occurring sorghum type. They found it is a natural hybrid characterized by limited flowering and the production of a few sterile seeds. Since flowering is very limited, the plant produces leaves throughout the growing season, which makes it a very desirable high-biomass forage grass for hay production. It can tolerate at least two harvests each growing season and is not invasive because of its sterile seeds and limited rhizome spread. This natural hybrid was released as a germplasm in FY 2016 and should significantly benefit cattle producers in the southern Great Plains.

**Native Thurber's needlegrass increases rangeland biodiversity.**

Biodiversity in many Western U.S. landscapes is reduced in part because of large-scale 19th-century plantings of non-native grasses such as crested wheatgrass. ARS scientists at Logan, UT, released native Princeton Thurber's needlegrass germplasm to increase regional plant genetic diversity by seeding native grass and legume species and to support the revegetation of degraded sites after disturbances such as wildfire and human disturbance. Thurber's needlegrass is a densely tufted bunchgrass that grows from 12 to 24 inches tall and provides valuable forage for livestock and wildlife. It is found in the semiarid Intermountain West in association with many rangeland plant communities, but is not commercially available. The release of Princeton Thurber's needlegrass creates an

opportunity for commercialization of a native needlegrass that is well adapted, good forage and will increase planting biodiversity. These efforts will support rangeland rehabilitation and the restoration of healthy rangeland plant communities.

### **Genetic markers for *Verticillium* wilt resistance in alfalfa.**

*Verticillium* wilt (VW) is an alfalfa disease that reduces forage yields up to 50 percent. Current breeding strategies rely greatly on selection based on visible plant traits, a process that is slow and inefficient for genetic improvement. An ARS scientist in Prosser, WA, in collaboration with Alforex Seeds, S&W Seed, Forage Genetics International, and the Noble Foundation, identified 11 genetic markers associated with VW resistance in two alfalfa populations. After these findings are validated, the markers identified in this study can be used for improving resistance to VW in alfalfa. The identification of genetic markers and associated development of germplasm for disease resistance will expedite the breeding process and facilitate a rapid development of alfalfa cultivars with improved VW resistance.

### **Unique perennial sorghum germplasm developed.**

*Sorghum propinquum* is an important species for developing perennial sorghum germplasm for forage and bioenergy feedstocks. *Sorghum perenniality* is achieved from below-ground rhizomes that survive low temperatures, but spreading rhizomes are usually associated with invasiveness. *S. propinquum* produces fewer and less invasive rhizomes than other species, which minimizes its invasiveness risk, but most sorghum hybrids that have been developed using *S. propinquum* as a parent have lacked desired cold tolerance levels. ARS researchers at College Station, TX, worked with Texas A&M University scientists to successfully double the chromosomes in diploid *S. propinquum*, which increased the

expression of traits for spreading rhizomes and winter survival. Seven unique tetraploid plants were recovered and can be used in breeding winter hardy perennial sorghum germplasm with favorable forage and bioenergy traits and with minimal invasive risk.

**‘ForageCrest’, a crested wheatgrass, improves rangeland productivity.**

Improved plant materials are needed to enhance rangeland productivity on harsh arid sites in the Western United States. The crested wheat grass cultivar ‘ForageCrest’ was released by ARS scientists in Logan, Utah, to improve productivity on rangelands receiving 8-12 inches of annual precipitation. ‘ForageCrest’ helps control the spread of invasive annual weed species such as cheatgrass and medusahead rye because it germinates earlier and grows more rapidly at colder temperatures than other perennial grasses. ‘ForageCrest’ co-exists with native grasses, forbs, and shrubs, is persistent, and provides adequate dry-matter yields with nutritional characteristics similar to or greater than current crested wheatgrass cultivars used in the Intermountain West, Great Basin, and Northern Great Plains regions. It also does not spread and does not cross with native species. The release of this cultivar provides ranchers with a new livestock forage and enhances productivity of U.S. rangeland grazing management while leaving existing native perennial grasses intact.

**A survey of North American *Astragalus* and *Oxytropis* taxa for locoweed toxin.**

Cattle that graze on western rangelands are occasionally at risk for consuming toxic forages. ARS scientists in Logan, UT, conducted a systematic examination of the toxin swainsonine in rangeland plants and found swainsonine in 48 *Astragalus* taxa (13 different species) and five *Oxytropis* taxa (four

different species). This list of plants that contain swainsonine will serve as an essential reference for ranchers who need to reduce the risk of livestock poisoning.

### **Rangeland restoration climatological report.**

Interpreting how weather affects revegetation treatments is critical for fire rehabilitation and rangeland restoration activities, especially at remote locations in the Western United States. ARS scientists in Boise, ID, and Woodward, OK, collaborated with university scientists to develop a procedure for creating location-specific microclimatology reports for rangeland restoration applications in the Great Basin. This report provides a description of historical weather variability and serves as a microclimatological supplement to Natural Resources Conservation Service Ecological Site Descriptions. It can also be used by Bureau of Land Management and Forest Service fire rehabilitation planners for more effective restoration of rangelands that have been severely disturbed by wildfire and invasive annual weeds.

### **Sagebrush rehabilitation increases habitat potential for sage grouse.**

Although the sage grouse is not protected under the Endangered Species Act, its future depends on the successful implementation of Federal and State management plans and the actions of private landowners, as well as a continuing focus on reducing invasive grasses and controlling rangeland fire. Innovative approaches to enhance degraded big sagebrush/bunchgrass communities are being tested by ARS scientists in Reno, NV. In the fall of 2013, the group mechanically treated old big sagebrush habitats in north-central Nevada using a Lawson Aerator, followed with seeding of perennial grasses and forbs to enhance wildlife and grazing resources. In the spring of 2016, the completed land treatment

was occupied by sage grouse, where two new strutting/lek (breeding) habitats were established through this range improvement practice. This innovative treatment has provided excellent wildlife and grazing values to the area.

### **Patch burn grazing management and grassland bird conservation in semiarid rangelands.**

Using fire management on semiarid grassland might enhance livestock production and wildlife conservation, but more information is needed about the role of fire in these ecosystems. ARS scientists in Cheyenne, WY, and Fort Collins, CO, studied patch burn grazing management in the shortgrass steppe to examine the consequences for the grassland bird community. They found that patch burn grazing management enhances habitat for the Mountain Plover, doesn't affect the abundance of McCown's Longspur and Horned Lark, and reduces the abundance of Lark Bunting and Grasshopper Sparrow. This work shows that patch-burn grazing management is an effective strategy for managing Mountain Plover habitat without affecting livestock production. But moderate cattle grazing does not generate the taller and denser vegetation needed to sustain breeding habitat for the full suite of native grassland birds, so additional management strategies must be developed if these goals are to be met.

### **Rapid selection of root systems for enhanced alfalfa forage yields.**

Plant breeders developing alfalfa cultivars with improved yields often focus on aboveground plant traits, but root systems may also enhance yields by improving water and nutrient uptake. Researchers previously found that alfalfa plants with a highly branched root system supported greater forage yields than plants with a typical root system, but it takes at least 20 weeks after planting before breeders can identify plants with the branching root phenotype. ARS researchers in Saint Paul, MN, determined that

the number and length of tertiary roots is a key measurement for distinguishing root types and developed a method to identify plants with a strong taproot or strong branch roots after only 2 weeks of growth. Plants could be identified consistently even when grown under conditions of mild drought stress, nutrient stress, and with nodulation by symbiotic bacteria. Several candidate genes were identified that were associated with the branching root phenotype. These findings will facilitate “root breeding” approaches aimed at modifying root system architecture to increase the absorptive capacity of roots for water and nutrients, which will increase alfalfa productivity, persistence, and resilience to environmental stresses.

**First-of-its-kind searchable database for condensed tannins.**

Condensed tannins are natural protein-binding substances in some forage species that protect forage protein from degradation during silage fermentation and rumen digestion. ARS researchers at Madison, WI, used data from scientific literature to create the Dairy Forage Research Center Condensed Tannin NMR Database. This instrument allows scientists to search for information about condensed tannins by structure, molecular formula, and other features. Citations for all literature references used in this database are also provided. The database is available free of charge on the ARS Web site. This resource can help scientists decipher the optimal chemical characteristics and concentrations of condensed tannins for improving protein utilization and milk production of dairy cattle, which will improve dairy producer profits.

**Growers profit from segregating wheat by protein content.**

Conventional harvest practices often include bulking high-protein wheat, which typically has a higher commodity value, together with other harvested wheat grains. ARS scientists in Pendleton, OR, designed and constructed a complete harvesting system consisting of: (1) an optical sensor for measuring grain protein on a combine harvester; (2) an electrical/mechanical device for physically separating low and high quality grain during harvest; and (3) software for calculating the best economic point at which to segregate grain into two bins. They tested this system to determine if segregating hard red spring wheat into two bins was more profitable than conventional bulking into one bin. Their results indicated that segregating wheat by protein content can under certain conditions increase the value of each bushel of grain; during years with large market price spreads and above average yields, net returns from segregating wheat were up to \$9.32 per acre greater than returns from bulking into a single bin. Growers can use this system to evaluate potential returns from grain segregation when economic conditions favor grain segregation, which will potentially improve producer profits.

**Corn growth simulation model testing reveals huge range of water-use predictions.**

Growth models that simulate corn (maize) growth predict plant water-use rates to estimate how many day's growth can occur following a rain or irrigation event before the soil water supply is exhausted. Eight years of water-use (evapotranspiration or ET) measurements collected by an ARS researcher at Ames, IA, were used for comparison testing as part of the international Agricultural Model Inter-comparison and Improvement Project (AgMIP). An ARS collaborator at Maricopa, AZ, compiled initial ET predictions from 24 models run by 16 research groups around the world, including ARS researchers at Maricopa, AZ, and Beltsville, MD. ET estimates from the models were found to vary by almost a

factor of four, and many of the predictions differed greatly from measured water use. This test conclusively identifies a weakness of many crop growth models and highlights the need for focused research to improve model routines for calculating crop water use. More realistic simulation model results will lead to better management and policy decisions by stakeholders ranging from producers to strategic decisionmakers.

### **High temperature impacts on corn hybrids.**

Projected increases of air temperatures have the potential to affect plant growth, but different crop varieties may be affected in different ways because of genetic variability. ARS researchers at Ames, IA, evaluated how high temperatures affected growth rates and grain yields of three corn hybrids. All three hybrids showed a faster rate of growth and large grain-yield reductions when grown under higher air temperatures that are expected to occur by the end of this century. The most significant air temperature factor affecting grain yield was exposure to high nighttime temperatures during the grain-filling period. These results will help the development of new varieties and management practices for crop production as environmental growing conditions change.

### **LTAR Network rangeland wind erosion research and model calibration.**

Wind erosion from rangelands degrades soil productivity, causes highway fatalities from reduced visibility, creates human health problems, and causes abrasive damage to infrastructure. Rangeland wind erosion data are needed to advance basic research, develop models for simulating how management actions mitigate rangeland erosion, and develop effective management options for reducing rangeland soil erosion. Working within the Long-Term Agroecosystem Research (LTAR) network,

scientists in Las Cruces, NM, coordinated the installation of wind erosion monitoring sites at three LTAR network locations. Installations at four other LTAR sites are scheduled to become operational during 2017. Instruments at the three completed sites are now collecting a suite of measurements (e.g., sediment mass flux, meteorological conditions, and dust deposition) with automated real time relay of the data to researchers. The long-term study of wind erosion on multiple ecological sites across the Western United States will provide data needed to assess how land management and land use affects rangeland wind erosion and support the development of mitigation strategies for protecting natural resources and human health and enhancing agricultural productivity.

**Novel and inexpensive hoe for weeding near plastic-covered produce beds.**

Controlling weeds along produce beds covered with plastic mulch is extremely difficult because standard hoes with rigid blades can easily tear the plastic. An ARS researcher in Salinas, CA, developed a light-weight, adjustable, and flexible bladed hoe made from 100 percent recycled material that efficiently slices through weeds without damaging the plastic mulch. This “recycle strap hoe” was a major weed management breakthrough for strawberry producers who use cover cropped furrows to conserve soil and reduce winter runoff. The hoe also works well for hand weeding vegetables without plastic mulch. This novel hoe was rapidly adopted by small-scale farmers in California and Hawaii, and has broad application world-wide for plastic mulch-covered beds that are typically used for high value vegetables and berry production.

**Long-term reduced till with continuous cropping reduces soil carbon and nitrogen losses.**

There is little information about how reduced till coupled with crop rotation affects the long-term status of soil carbon and nitrogen in cropping systems, so producers are unsure if these practices promote agricultural and environmental sustainability. ARS researchers in Sidney, MT, conducted a 30-year experiment to assess how low tillage and continuous crop rotation affected soil carbon and nitrogen on land originally converted from grassland. Their findings showed that no-till or reduced-till continuous cropping resulted in a 10-15 percent loss of pre-cropping soil organic carbon and total nitrogen, which is considerably lower than 30-35 percent losses resulting from a conventional-tillage, crop-fallow system. However, inorganic nitrogen levels increased more in the conventional system than in the no-till continuous cropping system. Soil organic carbon and total nitrogen are critical to soil quality and productivity, and this research indicates farmers can improve soil quality management by adopting no-till or reduced till with continuous cropping.

**No agronomic difference between GMO vs non-GMO corn.**

The rapid and widespread use of genetically engineered crops in the United States can be attributed largely to the perception that genetic modified organism (GMO) production is more cost-effective than conventional production, since the latter typically involves expenses associated with weed and insect control. ARS scientists in Brookings, SD, conducted studies to evaluate the agronomic characteristics of 18 commonly used corn hybrids, including three conventional hybrids and their corresponding transgenic modifications. There was no glyphosate use and no significant insect pest pressure during these experiments. Results showed that without significant insect and weed infestation, there were no

differences in grain yield or in above-ground corn biomass. Limited differences between hybrids in plant nutrient concentrations were not considered agronomically important, and are consistent with natural genetic variability among the genotypes tested, rather than the presence or absence of any particular trait. This study is expected to serve as a baseline for comparing data from future experiments conducted under various levels of insect or weed pressures, or following glyphosate applications, to more fully evaluate the costs and benefits of widespread GMO use. This information could be used by farmers when selecting the most cost-effective corn cultivars for production.

**National assessment of crop diversity.**

The potential vulnerability of U.S. production to catastrophic events from an increasingly homogenous U.S. cropping system has been raised from anecdotal accounts of declining crop diversity, but there has been no formal study to verify the accuracy and/or extent of this potential vulnerability. ARS scientists in Mandan, ND, Morris, MN, and collaborators used National Agricultural Statistics Service data to evaluate crop diversity changes at the U.S. county level over the past 34 years. Their results showed that national crop diversity has declined over the study period and that crop diversity notably declined in counties adjoining the Corn Belt. However, in some regions such as central North Dakota and coastal South Carolina, crop diversity increased. This study establishes a benchmark for assessing the vulnerability of U.S. production and provides a metric on the sustainability of U.S. production systems needed by strategic decisionmakers addressing the resilience of U.S. agricultural systems.

**Improved cover crop management can reduce the risk of increased corn seedling root diseases.**

Cereal rye cover crops in corn-soybean rotations have been shown to significantly reduce erosion, reduce losses of nitrogen and phosphorous, and increase soil organic matter. However, corn yields following cereal rye cover crops have been reduced during some years and in some fields, possibly because cereal rye may host pathogens that are sometimes transferred to corn seedlings after rye termination. ARS scientists in Ames, Iowa, showed in field and controlled environment studies that this scenario does occur for the fungal corn pathogens *Pythium* and *Fusarium*. Understanding how cover crops affect the incidence of disease in subsequent corn crops will enable the development of management strategies to overcome this risk factor. Farmers, extension personnel, crop advisors, and Natural Resources Conservation Service conservationists will be able to use this information to manage cover crops more effectively, which will lead to the greater environmental benefits of cover crop adoption with less risk to corn yield.

**Invasive species outcompete native species by the second week of growth.**

The spread of exotic plant species can reduce native plant populations and degrade ecosystems. For decades, ecologists have studied how plant characteristics differ between native plants and invasive plants and assessed if those characteristics can be used to predict invasiveness. ARS scientists in Temple, TX, investigated whether Johnsongrass, an introduced forage plant that has invaded native ecosystems, is successful in part because it begins its springtime growth earlier than other plants. They compared the factors promoting rapid growth in Johnsongrass and three native grasses and found Johnsongrass exhibits a growth advantage over natives by the second week of seedling growth. This advantage is reinforced by a more robust response to the effects of limited nutrient on growth, and more

rapid development of traits needed to ensure continued growth advantages. These characteristics likely contribute to Johnsongrass invasiveness in native grass-dominated communities. Understanding traits that confer invasiveness on Johnsongrass and other invasive exotic plants will help optimize application schedules for control strategies and preserve the health of native ecosystems.

**New tools for scientific information dissemination.**

Locating relevant literature is necessary to conduct meaningful research, identify appropriate land management techniques, and to build on and avoid duplicating previous efforts. JournalMap was developed by ARS scientists in Las Cruces, NM, to advance the ARS mission to develop and transfer appropriate solutions to agricultural problems in the United States and throughout the world.

JournalMap is the first true map-based search engine for scholarly publications and has expanded the ability of the scientific community to quickly and easily locate relevant knowledge in scientific literature relevant to specific study locations. JournalMap has continued to receive interest from researchers and the publishing industry. New agreements were established with publishers and scientific societies to geographically index manuscript content, resulting in the release of a new version of JournalMap with improved search capability. JournalMap has ignited a movement within the scholarly publishing community to capture and use location information as a fundamental component of knowledge discovery and application. This search engine enables scientists to locate relevant research results for specific or similar locations worldwide, avoid duplication of efforts, and assist with the identification of new analytical methods. JournalMap creates a major boost to the efficiency by which research is conducted worldwide.

### **Improved soil classification for precision farming.**

Traditional crop management accounts for little of the within-field variation affecting crop production, and thus frequently fails to produce maximum potential yields. Successful implementation of precision farming strategies can compensate for this variation when within-field soil classification is available. ARS researchers at Columbia, MO, and collaborators developed and tested the performance of a new soil classification system called “Environmental Response Units” (ERU) by examining how well it accounted for yield variation within farmers’ fields compared USDA soil maps ( Soil Survey Geographic Database or SSURGO). They used ERU classification to define within-field management zones in over 400 production fields in four Midwest U.S. States and found that ERU classifications accounted for more yield variation on average and produced better yield results in 86 percent of the fields. Soil classification with ERU soil maps better delineates soil and landscape characteristics within fields and can better guide the use of precision agriculture variable rate technologies. Farmers can use these findings to optimize seed and fertilizer inputs that match production potential within fields. Matching input applications to a better characterized soil resource improves the cost-effectiveness of agricultural production and minimizes field losses of agrichemicals, which furthers production sustainability and natural resource protection.

### **Evaluation of nitrogen decision tools for corn.**

Many decision-support tools are now available to help manage nitrogen fertilizer applications, but corn farmers are often uncertain which tools work best for their specific conditions. ARS researchers at Columbia, MO, and cooperators reviewed crop reflectance sensor decision rules for nitrogen management and found that the sensors could provide an in-season prediction of yield potential and crop

nitrogen response but that additional information on growing conditions was also needed to optimize nitrogen fertilizer recommendations. The researchers also compared corn nitrogen fertilization recommendations based on canopy reflectance sensing to nitrogen fertilization based on crop growth modeling using field data. Although the nitrogen rate prescribed by model-based approaches was closer to the recommended optimal nitrogen rate, recent versions of reflectance sensor-based decision rules appear to be closer to matching model-based recommendations. Farmers benefit from this research because they can reduce excess nitrogen applications and costs by varying fertilizer applications within a field. If fertilizer can be better matched with crop need, nitrogen fertilizer loss to the environment will be reduced and production costs may be reduced, thus helping to protect soil, water, and air resources while increasing net economic gains for producers.

#### **Alternate methods to manage pigweed in conservation tillage.**

Weed control in conservation tillage is currently under threat due to herbicide resistant pigweed and other troublesome weeds. Inversion tillage, in which a layer of soil (often 6 -12”) is flipped over to bury surface residues (and associated weed seeds, spores and insect larva and eggs), is being advocated by some in cooperative extension because it can effectively reduce weed emergence. An ARS researcher in Auburn, Alabama, and cooperators conducted a multi-State field experiment to compare weed control management via integrating high-residue cover crops and herbicides following conservation tillage that included a strategic inversion tillage system and a winter fallow conservation system. Results indicated that a one-time inversion tillage operation followed by a return to conservation tillage may help reduce weed density. But this system probably does not provide adequate control when an extremely high population density of glyphosate-resistant *Amaranthus* is present, which highlights the continued need for a highly effective herbicide system. This research shows cropping systems that integrate practices

such as high-residue cover crops, crop rotation, and alternative herbicide systems can be used to improve herbicide-resistant-weed control. Results from this study will help farmers increase weed control and reduce their reliance on tillage to manage hard-to-control weeds.

**Decision aid for comparing rental agreements.**

Agricultural producers are faced with a variety of cropland rental options, such as cash rent, share rent, and flexible cash rent. ARS researchers at Auburn, AL, developed a decision tool for comparing different cropland lease agreements, including flexible cash rents, for up to five crops and/or management systems. Flexible cash rents allow tenants and landowners to share the risk associated with uncertain commodity prices and yields. With the Cropland Rental Tool (CROPRENT), users can explore how different lease agreements affect their operation based on production expenses and price and yield data. This tool can be used for a variety of commodities regardless of geographic location and by a diverse audience, including Extension educators, landowners, and tenants. The Cropland Rental Tool and a User Manual can be downloaded free of charge at the following Web site:

[www.cottoninc.com/fiber/AgriculturalDisciplines/AgriculturalEconomics/Cotton-Farming-Decision-Aids](http://www.cottoninc.com/fiber/AgriculturalDisciplines/AgriculturalEconomics/Cotton-Farming-Decision-Aids).

**Banding placement of pelletized broiler litter maintains cotton yield and improves producer profits.**

Many row crop farmers in the southeastern United States who use broiler litter to fertilize cotton disregard the residual nitrogen supplied by the broiler litter application during the preceding year, and apply the full nitrogen needs of cotton from inorganic nitrogen sources the first year after broiler litter

use ceases. This practice often leads to over-application of nitrogen, which generates associated economic loss and potential environmental harm. ARS scientists at Mississippi State, Mississippi, compared the residual effects of precision band placement of pelletized broiler with recommended commercial nitrogen fertilizer applications and found that similar yields were sustained when the prior litter plots were fertilized with a reduced rate of inorganic fertilizer nitrogen, which facilitated the uptake of litter residual nitrogen already in the soil. This strategy reduces the use of inorganic nitrogen fertilizers and enables growers to optimize the cost-effectiveness of their nutrient management practices.

**Soil phosphorus composition is affected by agricultural system complexity.**

Integrated crop-livestock systems are gaining traction as a potential method of sustainable agriculture intensification, but more information is needed about nutrient cycling in these mixed systems. An ARS soil scientist in Raleigh, NC, and international colleagues analyzed soil at four sites in the Brazilian States of Parana and Rio Grande do Sul for different fractions of phosphorus. They found that cropping systems with greater complexity (where cattle grazed cover crops or in an agroforestry system) resulted in surface soil concentration of plant-available orthophosphate and lower concentrations of organically derived phosphorus components. The results of this research suggest that more complex cropping systems with livestock and trees could be valuable approaches for enhancing phosphorus cycling and mitigating losses of phosphorus to the environment, which would help preserve global supplies of limited phosphorus reserves.

**Crop production varies considerably due to meteorological pattern variability.**

Scientists in Beltsville, MD, analyzed data from a long-term agroecological research project and found that annual fluctuations of corn and soybean yields varied on a periodic basis, with periods lasting about 4½ years. Precipitation and air temperature during critical periods in the early and late growing seasons explained much of the yield variability, with precipitation during the late vegetative and early reproductive phases of crop growth accounting for the majority of yield variability for both crops under five different management systems. Meteorological conditions at the site were partially explained by El Niño Southern Oscillation sea surface temperature (SST) patterns; the lowest critical period precipitation and resulting yield anomalies always occurred during years with extreme La Niña and El Niño SST anomalies, and the highest critical period precipitation and resulting yield anomalies always occurred during years with neutral SST anomalies. The efficiency of grain yield per unit of precipitation was higher in conventional than organic systems, highlighting the importance of crop management for optimizing production when responding to meteorological variability. Farmers can use this information to guide production decisions, and strategic decisionmakers may find these results helpful when developing policies affecting agricultural production.

**Legume cover crop performance is critical to determining poultry litter application rates.**

Applying animal coproducts such as manure to meet crop nitrogen needs often results in soil phosphorus buildup that poses environmental challenges. Legume cover crops such as hairy vetch can be used in combination with animal coproducts to help balance nitrogen and phosphorus inputs, but information is needed on effective application rates. ARS scientists in Beltsville, MD, conducted a 2-year study and found that when hairy vetch produced a lot of biomass, neither organic amendments nor mineral

fertilizers increased corn yield further, indicating that vetch alone could meet all of corn's nitrogen needs. During a year with poor vetch performance, vetch provided no benefit to corn, while organic amendments were applied at rates that increased corn grain yield without raising concerns of soil phosphorus buildup. While benefits of the four organic amendments were very similar, costs differed substantially. Economic returns from using poultry litter were substantially greater than for the other three materials (pelletized poultry litter, feather meal, and a pelletized poultry litter-feather meal blend). Organic and conventional farmers can use these results to optimize planting hairy vetch cover crops, and these findings can inform decisions by policymakers and other advocates seeking to balance production and environmental consequences of agriculture.

**Projecting climate change effects on Eastern Seaboard crop yields.**

Projected climate change impacts on agriculture vary by crop and location, and producers and planners need to understand these impacts at a sub-regional scale to develop adaptation strategies. ARS researchers in Beltsville, MD, used SPUDSIM and MAZSIM crop growth and yield simulation models with soil, management, and climate data to simulate how a changing climate might affect potato tuber yields and corn silage at the sub-county level in the northeastern U.S. seaboard region. The results showed a potential 50-percent reduction of potato yield and a potential 19-percent loss of corn silage if no adaptation measures are implemented. These impacts were comparatively larger in Northern States than Southern States in large part due to warming temperatures and dryer, less humid air used with the climate predictions. The results provide an initial assessment of climate impacts on two important crops and can be used by scientists and policy planners to explore adaptation mechanisms, including a more optimal distribution of the current production system under future climates.

**Long-term field management database.**

Agricultural management strategies can be used to mitigate water quality problems, and long-term watershed and farm management datasets are unique resources for supporting water quality research, management, and policy. However, these datasets are difficult to develop because they must protect the privacy of farmers and land owners without compromising the accuracy of specific spatial and temporal data. ARS researchers in University Park, PA, developed a novel framework for recording land-management, water-quality, and related data that expands the use of these datasets across the research community and offers a model for other database management efforts. The framework's initial database contains long-term field management information for 15 farms and nearly 300 fields within a long-term experimental watershed located in a non-karst portion of Pennsylvania's Ridge and Valley Physiographic Province. This database supports research that helps farmers meet long-term production, land stewardship, and water-quality goals and is expected to support the future development of management strategy options.



## **CROP PRODUCTION AND PROTECTION**

### **National Programs:**

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

### **Using genetic diversity to breed cotton with nematode resistance.**

Reniform nematodes are roundworms that cause significant economic loss to cotton each year, and because new races of nematodes frequently infest cotton, breeders are continuously seeking new sources of resistance. The USDA National Plant Germplasm System (NPGS) contains more than 1,600 types of cotton seed that may contain resistance, but it would be time consuming and costly to screen all of them. ARS researchers in Stoneville, MS, used genome-wide DNA sequencing data to compare 375 varieties of Asiatic cotton germplasm from the NPGS and found resistance to reniform nematode in 122 varieties. As lines of cotton with various genes for nematode resistance continue to be identified, the DNA sequencing data will be used to develop DNA markers that can be used to more rapidly transfer the resistance genes to upland cotton.

**Identification of a novel disease susceptibility gene in wheat.**

*Septoria nodorum* blotch (SNB) is a severe fungal disease of wheat worldwide. ARS researchers in Fargo, ND, identified a new gene in wheat that makes it susceptible to SNB. They also developed molecular markers that can be used by wheat breeders to monitor the presence of the gene among their breeding lines, which will help them eliminate this gene from varieties released to wheat growers.

**Two new watermelon breeding lines show resistance to *Fusarium* wilt.**

*Fusarium* wilt of watermelon is an economically significant disease. ARS researchers in Charleston, SC, developed seed from two *Fusarium*-resistant varieties of watermelon, USVL246-FR and USVL252-FR, and have distributed them to more than 20 seed companies for evaluation. Several companies have found the new lines to be more resistant than other breeding lines currently in use, and two companies have begun using these resistant lines in their own breeding programs. These highly resistant watermelon lines provide strong protection for the U.S. watermelon industry against the damaging *Fusarium* wilt disease.

**Using genes to fight citrus greening.**

*Huanglongbing* disease, also known as citrus greening, is a destructive invasive disease of citrus that has spread throughout Florida and threatens other citrus-producing parts of the country. One method of fighting the disease is by developing citrus tree varieties with resistance to the disease. ARS researchers in Parlier, CA, and the Central California Tristeza Eradication Agency in California, and the Citrus Research and Education Center in Florida, successfully modified the expression of a citrus gene using a

citrus tristeza virus (CTV) vector, which proved the usefulness of this approach. Additional research is being conducted with this vector to alter other citrus genes that induce premature fruit drop and the plugging of the nutrient transport system in the plants. The CTV vector can be further modified to produce antimicrobial peptides and RNA interference to specifically target the citrus greening pathogen and the insect that spreads the disease. If regulatory approval is obtained, this process could be used for short- to mid-term control of citrus greening to reduce the reliance on insecticides to manage the insect vector.

### **Resistance to cereal cyst nematode found in adapted wheat varieties.**

Cyst nematodes are responsible for about \$51 million in annual losses in the dryland wheat fields of the Pacific Northwest. Currently, farmers have no options for using chemicals or resistant plant varieties to control the pathogen. ARS scientists in Pullman, WA, developed several wheat varieties, including SY Steelhead, Svevo, and ARS Crescent, and screened them for nematode resistance in both greenhouses using infested soil and in known infested fields. These new varieties are available for immediate use by growers to manage the disease. The discovery of this resistance will aid plant breeders in quickly developing additional resistant varieties without having to breed out undesirable characteristics that exist in wheat seeds not well adapted to the Pacific Northwest.

### **New findings in Ug99 wheat stem rust resistance genes.**

Stem rust is an important disease of wheat in the United States and around the world that can cause severe crop losses, and an extremely virulent form of this pathogen from Africa, Ug99, currently threatens global wheat production. While the pathogen has not yet entered the United States, ARS

scientists in St. Paul, MN, are using preventive breeding to develop new forms of wheat resistant to it; for example, by using DNA sequence information to develop wheat varieties that carry multiple genes for Ug99 resistance. The scientists have been able to transfer a gene, Sr59, from rye into wheat that conveys resistance to Ug99. The DNA sequences of three additional Ug99 resistance genes (Sr22, Sr45, and Sr50) were also identified in cooperation with international collaborators. Continued selection and transfer of genes into wheat that resist stem rust is essential for the development of wheat cultivars with resistance to Ug99.

### **Molecular marker developed for wheat blast pathogen.**

Wheat blast disease is a major threat to wheat production in South America, where it was first reported 30 years ago. The disease had not been detected outside of South America until spring 2016, when it was found in Bangladesh. This discovery confirmed that the potential is high for the disease to spread to other wheat-producing countries, including the United States. ARS researchers in Frederick, MD, developed a diagnostic assay that is specific for the fungal pathogen that causes the disease, *Magnaporthe oryzae* Triticum pathotype (MoT), and used it to identify and characterize the isolates obtained from the first outbreak of wheat blast in Bangladesh. ARS scientists compared the genomes from 4 MoT isolates with those of 16 *M. oryzae* isolates collected from 10 different host species. The end result was the identification of a marker, MoT3, which can differentiate MoT isolates from other *M. oryzae* isolates. The information from this research, with the molecular primers, was published in a peer-reviewed journal article. The assay could be useful to government, academic, and private diagnosticians for detecting and identifying MoT isolates, and for monitoring outbreaks of wheat blast disease.

**Reducing the incidence and severity of almond leaf scorch disease.**

Significant variability in disease intensity exists among regions and cultivars affected by almond leaf scorch disease in California, the only State that produces almonds commercially. ARS researchers in Parlier, CA, evaluated *Xylella fastidiosa*, the bacterium that causes leaf scorch disease on almond trees grafted onto four rootstocks. One rootstock, ‘Nemaguard’, a rootstock widely used because of its resistance to nematodes, promoted complete pathogen elimination and remission of leaf scorching symptoms, which indicates that an *X. fastidiosa*-resistant trait exists in the rootstock. By using ‘Nemaguard’, growers in California are expected to be able to maintain a low disease incidence.

**Identifying new strains of citrus Tristeza virus in California that do not require quarantine.**

Citrus tristeza virus (CTV) has caused hundreds of millions of dollars in losses to citrus producers throughout the world. Infected trees in California are detected using a protein (antibody) test that is specific for the MCA-13 strain of CTV, which causes rapid tree decline and death. As part of the overall effort by the California Department of Food and Agriculture (CDFA) to eradicate CTV, trees that test positive for the MCA-13 strain are removed from orchards and destroyed. ARS scientists in Parlier, CA, in collaboration with the Central California Tristeza Eradication Agency (CCTEA) and tree fruit scientists in Bari, Italy, identified two new strains of CTV that also tested positive using the antibody test specific for the MCA-13 strain. The strains, RB and S1, produce mild disease symptoms in citrus, not the rapid death and decline associated with MCA-13. In addition, the two new strains can be distinguished from MCA-13 on the basis of their RNA sequences. These results, which have been presented at meetings of citrus researchers, offer a better way to detect mild strains of CTV which

allows growers to preserve infected trees for productive purposes instead of removing and destroying them. Both the CDFA and the CCTEA have applied this information in their CTV eradication efforts.

### **Development of a rapid and sensitive assay to identify select agent strains of *Ralstonia***

#### ***solanacearum*.**

*Ralstonia solanacearum* is a bacterium that causes millions of dollars of losses in a wide range of crops. One strain in particular, the r3b2 subgroup, is such a threat to U.S. agriculture that it has been designated a select agent, and new regulations require that all strains of the bacteria be considered select agents until they are shown not to be r3b2. To prevent the r3b2 strain from entering the United States, ARS researchers in Beltsville, MD, developed a new molecular assay that improves the specificity and confidence in detecting the r3b2 subgroup of the pathogen. The new assay allows for quick, easy, and reliable detection and differentiation of the r3b2 strains of *R. solanacearum*. The technology has been transferred to the USDA Animal and Plant Health Inspection Service as a general assay tool and is being used in two portable (onsite) analysis formats for the rapid and accurate detection of this devastating bacterial pathogen.

### **Major yield losses caused by stripe rust prevented in 2016.**

Weather conditions in the 2015–2016 season were highly favorable to stripe rust meant that the disease started early and developed into an epidemic in the Pacific Northwest and other regions of the United States. ARS scientists in Pullman, WA, conducted field surveys and used recently developed prediction models to make accurate forecasts of the wheat stripe rust epidemic early enough in the season to offer farmers timely and accurate recommendations for fungicide application, and thereby prevented major

yield losses. Washington State University colleagues posted the information from the survey on a Web site ([www.striperustalert.wsu.edu](http://www.striperustalert.wsu.edu)) to inform Washington farmers. Accurate forecasting in combination with field surveys by collaborating scientists throughout the country proved to be an effective disease management method in 2016 for controlling a stripe rust epidemic in the Pacific Northwest.

**Fescue suppresses plant-parasitic nematodes.**

Plant-parasitic nematodes (roundworms) can be difficult to control once they infest a field. Tall fescue is widely used as a forage and turfgrass, and for stabilizing soil and preventing erosion. A fungus growing within tall fescue improves plant vigor in drought and poor soil conditions, confers pathogen resistance, and produces compounds that are toxic to insects and other animals. ARS research conducted in Beltsville, MD, and Byron, GA, led to finding that planting the tall fescue cultivar Jesup (Max-Q) before establishing peach tree orchards suppresses several nematode species. Additionally, root and shoot extracts and root exudates of the fescue were found to be especially toxic to one of those species, root-knot nematode. This information is being used by the researchers to identify chemical compounds that contribute to suppression of root-knot nematodes for the development of alternatives to the current use of synthetic pesticides to suppress nematode populations.

**Galls on corn caused by *Ustilago maydis* may be contaminated with mycotoxins.**

People in some cultures consume corn smut, a fungal reproductive structure on corn caused by an infection with the *Ustilago maydis* fungus. ARS scientists in Stoneville, MS, examined field and commercial samples of the galls (fungal structures) and developed a simple analytical procedure to test for the presence of mycotoxins. Using the procedure, the scientists found fumonisin, aflatoxin, and

zearalenone among the samples. The discovery of these mycotoxins in these food products has health implications for people who eat the products. This research will be used to develop strategies and methods to reduce mycotoxin contamination in this food group, which in turn, will lead to better nutritional knowledge and better human health.

**New sources of resistance to zonate leaf spot and rough leaf spot in sorghum.**

Global climate change is likely to alter the frequency and severity of fungal diseases such as zonate leaf spot and rough leaf spot, which in humid weather conditions can cause significant sorghum losses. New disease-resistant sorghum varieties are needed and are a major priority for sorghum growers. ARS scientists in College Station, TX, and Mayagüez, PR, working with collaborators from Texas A&M University and Kansas State University, evaluated 181 sorghum varieties for resistance to zonate leaf spot and rough leaf spot. Eight varieties were found to be highly resistant to both diseases. This work has identified new lines that sorghum breeders and other researchers can use to develop critically needed new germplasm with resistance to these two diseases.

**Antibodies developed to a select agent plant pathogen.**

*Rathayibacter toxicus* is a select agent plant pathogen due to the bacterium's ability to make a toxin in forage grasses lethal to livestock. Annual production losses in Australia from this pathogen amount to \$40 million. Because of the potential threat to U.S. agriculture and food supplies, accurate and rapid diagnostics are needed to distinguish *R. toxicus* from other *Rathayibacter* species already existing in the United States that are critical to food security and trade. ARS researchers in Frederick, MD, have generated a highly specific polyclonal antibody that specifically detects *R. toxicus* and which will allow

detection of the pathogen by a simple immunoassay. The peptide used to generate this antibody is now being used to generate monoclonal antibodies for transfer to the USDA Animal Plant Health Inspection Service for use in rapid, on-site biosensor applications.

**A wheat gene contributing to *Fusarium* head blight resistance is identified.**

*Fusarium* head blight (FHB), a major disease and threat to wheat and barley production, is caused by the fungus *Fusarium graminearum*, which produces the mycotoxin deoxynivalenol (DON). The disease is found throughout the spikes and kernels of wheat and barley. ARS researchers in West Lafayette, IN, and their international collaborators found that a specific gene in wheat is critical for DON tolerance. The scientists found that overexpression of this gene in transgenic wheat creates greater FHB resistance in the resulting wheat lines. The use of this gene is not available to traditional breeders, though scientists using gene editing would be able to use it to develop wheat and barley with enhanced FHB resistance.

**Nutritional components of xylem sap are correlated with glassy-winged sharpshooter egg maturation.**

The glassy-winged sharpshooter is the most important insect vector of *Xylella fastidiosa*, a bacterium known for causing several diseases in grapes. The glassy-winged sharpshooter reproductive rate is highly variable and dependent on the adult diet, but little is known about the sources of that variability or the nutritional requirements for egg maturation. ARS researchers in Parlier, CA, analyzed the chemical profile of the xylem sap of plants that host the glassy-winged sharpshooter and found that the

amino acid composition in sap encouraged higher rates of egg production and maturation. This new information will help provide guidance to breeders and growers in identifying and developing grape cultivars unable to support sharpshooter populations.

### **Wheat genes with resistance to stripe rust mapped.**

Growing wheat varieties resistant to stripe rust is the most effective, economical, and environmentally friendly way to control the disease. In 2016, ARS scientists in Pullman, WA, completed stripe rust resistance mapping studies of three genes in spring wheat variety ‘W18’, one gene in the spring wheat variety ‘PI 184597’, and one gene in the winter wheat variety ‘Tres’. The location of these genes and their molecular markers are proving useful to ARS, university, and industry breeders in developing wheat varieties with resistance to stripe rust and helping to characterize the races of this fungal pathogen.

### **Release of nematode-resistant cotton lines.**

Among pests, root-knot and reniform nematodes cause the greatest yield losses in cotton (approximately 4 percent of potential yield). Nematodes also act synergistically by increasing the severity of seedling diseases and *Fusarium* wilt, which results from tissue damage that occurs during their feeding activities. ARS researchers in College Station, TX, working jointly with colleagues at Texas A&M AgriLife Research and with Cotton Inc., released eight new nematode-resistant germplasm varieties. All eight varieties are resistant to the reniform nematode and five are resistant to the root-knot nematode. The varieties have elite agronomic performance traits valuable to plant breeders who want to reduce yield losses and lower costs of pest control in cotton.

**Draft whole genome sequencing of *Xylella fastidiosa* subspecies *fastidiosa* Stag's Leap strain.**

Pierce's disease, caused by the bacterium *Xylella fastidiosa*, costs California grape growers \$104 million in control costs and losses each year and endangers the State's multi-billion dollar grape and wine industry. Analysis of whole genome sequences of *X. fastidiosa* strains from different geographical origins and host plants is necessary to better understand this pathogen, but accurate methodologies to assemble, annotate, and analyze these genomes of *X. fastidiosa* were lacking. ARS researchers in Parlier, CA, in collaboration with scientists at National Chung Hsing University in Taichung, Taiwan, developed improved methods to analyze bacterial genomes that led to the sequencing, assemblage, annotation, and analysis of the genome of the Stag's Leap strain of *X. fastidiosa* obtained from Napa Valley, California. Increased accuracy in bacterial genome analysis and greater knowledge of *X. fastidiosa* strain characterization is another step in the ongoing research to identify the biological characteristics of the bacterium that could lead to novel methods of disease control.

**RNA interference methods to control whiteflies.**

Whiteflies are among the most destructive insect pests of American vegetables, fruits, cotton, and ornamentals, causing millions of dollars in losses annually. There is very little resistance in most of these important crops to either whiteflies or the viruses they transmit, thus the pest is primarily controlled by insecticide applications. ARS researchers in Salinas, CA, used whitefly genome sequences to design RNA interference (RNAi) molecules that were then tested for their ability to control whiteflies. Several of the RNAi molecules were quite effective at killing whiteflies in laboratory conditions. These discoveries provide proof that RNAi technologies can be used to control whiteflies in

more environmentally sustainable ways, and that future whitefly control will be possible using methods other than insecticides.

### **Determining the prevalence of mosaic virus in imported lily bulbs.**

Lilies are a valuable, internationally traded ornamental crop, with cut flower production in California alone worth more than \$56 million wholesale. Plantago asiatica mosaic virus (PIAMV) was recently detected in lily bulbs imported into the United States from the Netherlands, where losses of up to 80 percent have been reported in cut-flower lily production. Unfortunately, there have been no studies to indicate the prevalence of PIAMV in different imported lily types, and rapid diagnostic methods for detecting the virus in infected bulbs did not exist. To address this paucity of information, ARS scientists in Beltsville, MD, in collaboration with colleagues at the University of Maryland, tested different imported lily types from the Netherlands for the presence of PIAMV to identify the types of lilies are most likely to be infected with the virus and the greatest threat to the U.S. cut flower market.

Consequently, the scientists developed a rapid protein-based assay to detect the virus and tested different imported lily types for the presence of PIAMV. These advances contribute critical information on what types of lilies are likely to be infected with the virus and provide diagnostic capabilities to detect the virus in seed stocks of this highly valuable crop.

### **Identification of genes associated with fungicide resistance in a sugarbeet pathogen.**

*Cercospora* leafspot of sugarbeet is caused by the fungal pathogen *Cercospora beticola*. The disease causes severe losses in sugarbeet production throughout the United States and is primarily controlled by fungicide application. Unfortunately, fungicide resistance is increasing. To gain a better understanding

of the genetic control of fungicide resistance, ARS researchers in Fargo, ND, carried out a genetic analysis of fungicide-resistant and fungicide-sensitive isolates of *C. beticola*. One gene, Cyp51, was found to be much more active in fungicide-resistant isolates than in fungicide-susceptible isolates, and several other genes were also identified that could be used to distinguish between fungicide-resistant and fungicide-sensitive isolates. These findings increase the fundamental understanding of the genetic basis for fungicide resistance in *C. beticola* that could lead researchers to develop prescriptive uses of fungicides for sugarbeet production in more environmentally sustainable ways.

### **Blueberry cultivars with resistance to root rot pathogen.**

*Phytophthora cinnamomi* is an important soilborne pathogen of blueberry worldwide that causes root rot and limits establishment of new blueberry fields. Working with collaborators at Oregon State University, ARS scientists in Corvallis, OR, evaluated 18 blueberry cultivars for resistance to *P. cinnamomi* and discovered six with resistance to the pathogen. This information provides growers, and particularly organic growers who cannot apply fungicides to manage root rot disease, with an alternative method for controlling this pathogen.

### **Genetic characterization of the fungus that causes root rot in soybean.**

The fungus *Fusarium virguliforme* causes root rot and sudden death syndrome in soybean, both of which produce significant reductions in soybean yields each year. ARS scientists in Urbana, IL, and their collaborators showed that *F. virguliforme* produces a diverse set of cell wall-degrading enzymes, including several that have not been reported in other plant pathogenic fungi. The research team also identified *F. virguliforme* toxin genes that when they were expressed in plants induced foliar symptoms

of soybean sudden death syndrome. The enumeration of the specific types of cell wall-degrading enzymes and the multiple toxins produced by *F. virguliforme* will facilitate strategies to reduce the severity of root rot and sudden death syndrome by breeding transgenic varieties of soybean that express proteins to inhibit these toxins and enzymes, thereby helping in the management of this economically important disease of soybeans.

#### **Novel treatment for controlling strawberry diseases.**

Strawberry production in high- and low-tunnel cultures presents significant challenges in disease control. ARS researchers in Kearneysville, WV, found that ultraviolet C (UV-C) irradiation, followed by a 4-hour dark period, can control gray mold and anthracnose infection in the fruit of strawberry plants. This technology represents an effective alternative to the use of chemical fungicides, and its use is especially applicable to urban horticulture and high- and low-tunnel production systems.

#### **Herbicide resistance in yellow nutsedge, a major weed in rice production.**

Yellow nutsedge is a significant weed in Arkansas rice, and it is controlled by frequent use of the herbicide halosulfuron (sulfonylurea). Halosulfuron belongs to a class of ALS-inhibiting herbicides that target essential acetolactate synthase (ALS) plant proteins and eventually kill the plant. In 2012, halosulfuron failed to control yellow nutsedge when it was applied at the field rate specified on the product label. ARS scientists from Stoneville, MS, and cooperators examined the resistance level, cross-resistance, and resistance mechanism in samples of the resistant weed and found that it was resistant to halosulfuron application rates that were 256 higher than field dose levels. The resistant plants also survived treatment with seven other ALS-inhibiting herbicides at labeled field rates. The

scientists found that the ALS enzyme from the resistant plant was 2,540 times less responsive to halosulfuron than a susceptible plant, and that resistance appeared to be conveyed by a mutation that resulted in a single amino acid substitution in the ALS enzyme. Their findings confirm that a single, target-site mutation conferred a high degree of resistance in yellow nutsedge and conferred cross-resistance to other ALS-inhibiting herbicide families. These findings provide researchers with information needed to develop effective herbicides for controlling this resistant strain of yellow nutsedge.

#### **Characterization of 49 viruses that infect fungal pathogens of soybean.**

Soybean provides essential nutrients for both humans and food animals and is an important source of bioenergy. Each year, fungal diseases significantly reduce soybean yields and seed quality, but some fungal viruses reduce the ability of other pathogenic fungi to induce disease. ARS scientists in Urbana, IL, and their collaborators identified viruses that infect the fungi that cause five widely prevalent soybean diseases: anthracnose, charcoal rot, *Phomopsis* seed decay, *Rhizoctonia* root rot, and *Sclerotinia* stem rot. Because some of these viruses reduced the virulence of their fungal hosts, these results could potentially widen the range and diversity of biological agents deployed for use to manage fungal diseases of soybean. The scientists are using these findings to evaluate the ability of the viruses to reduce virulence and to assess potential methods for transmitting the viruses to the fungal pathogens.

#### **New technology for controlling gypsy moths.**

The voracious gypsy moth is a devastating pest that is rapidly spreading across the United States. It defoliates millions of acres of hardwood forest annually, often in U.S. urban green spaces. ARS

scientists in Beltsville, MD used gypsy moth RNA to develop technologies for creating RNA interference (RNAi)-based molecular biopesticides specifically designed to deactivate and silence genes crucial to gypsy moth survival. Gypsy moth caterpillars that consumed these compounds were less able to reproduce. These highly specific biopesticide technologies will be useful tools for controlling gypsy moth pests and protecting U.S. trees from infestations, while sparing non-target insects.

**RNA interference-based molecular biopesticides effective against brown marmorated stink bug.**

The brown marmorated stink bug (BMSB), an invasive insect native to Asia, has rapidly emerged as a major insect pest in the United States. Well known to the public as an irritating indoor nuisance pest, BMSB is a piercing/sucking feeder that poses considerable ecological and economic threat to specialty crops, including apples, stone and pome fruits, grapes, ornamental plants, vegetables, seed crops, and staple crops such as soybean and corn. ARS scientists in Beltsville, MD, designed novel double-stranded RNA interference (RNAi) biopesticides to deactivate and silence specific genes critical to BMSB. When fed to BMSB, these compounds inhibited development and reduced fecundity. These new and highly specific molecular biopesticide technologies will be useful tools for controlling BMSB pests without affecting non-target insects.

**A new tool for fighting citrus greening disease.**

Citrus greening is one of the most serious citrus plant diseases in the world and poses a grave threat to the economic survival of Florida's citrus industry. ARS researchers at Fort Pierce, FL, and colleagues developed bacterial treatments that penetrate citrus trees to reach the phloem and demonstrated these treatments reduce bacterial loads and improve tree health. The data from this research were presented to

the State of Florida and the U.S. Environmental Protection Agency for discussions that led to the approval of these bactericides for use in Florida. It is estimated the bacterial formulations are now being used on the majority of Florida's commercial citrus orchards to help prevent and mitigate the spread of citrus greening.

**Goss's wilt in sweet corn is not affected by the use of the herbicide glyphosate and transgenic traits.**

Claims have been made in recent years that glyphosate use and transgenic traits in corn have increased its susceptibility to plant diseases, including Goss's wilt. ARS researchers in Urbana, IL, Beltsville, MD, and University of Mississippi found that Goss's wilt incidence was independent of glyphosate use and transgenic traits in sweet corn. In addition, they determined that sweet corn yields improved with the use of these technologies. This research dispels negative claims about the effects of glyphosate and transgenic traits on corn, and can help farmers make informed decisions about corn cultivar selection and production management.

**Wild potato germplasm resistant to potato psyllid.**

The potato psyllid is the vector for the pathogen associated with zebra chip disease of potato, which renders potato tubers unmarketable. Wild potato germplasm contain favorable genetic traits, including insect resistance, which can be bred into marketable potato cultivars. ARS researchers in Wapato, WA, and Sturgeon Bay, WI, screened populations of a wild potato species, *Solanum verrucosum*, for resistance to potato psyllid and discovered two populations that are highly resistant to the psyllid. These

populations will be used by breeders to develop new cultivars resistant to potato psyllid, which would provide a cost-effective control of the potato psyllid and zebra chip pathogen without insecticides.

**Improving identification of optimal thermal ranges in western cherry fruit flies.**

The potential of western cherry fruit fly to invade new geographic areas is thought to be limited by its intolerance to extreme temperatures, which shut down its metabolic activity and development. These effects can be measured by oxygen consumption and metabolic rate. ARS scientists in Wapato, WA, determined that the fly's tolerance of temperature extremes is affected by age. Newly emerged flies showed the broadest tolerance to temperature extremes and fly tolerance to temperature extremes declined with age, with 28-day old flies exhibiting the most limited tolerance. These results were used to refine a model that predicts the potential national and global distribution of the western cherry fruit fly. The U.S. Pacific Northwest sweet cherry industry is using the model to renegotiate current and establish new trade agreements with countries that maintain quarantine restrictions against the western cherry fruit fly, but where modeling indicates no risk of invasion.

**National fungal collection established for endophytes associated with invasive plants.**

Fungi that live symbiotically within living plants are called endophytes and research has shown they can benefit crop plants, but more information is needed about how they support the success of invasive weeds. ARS scientists in Peoria, IL, collected, identified, cultured, and stored more than 350 fungal isolates from medusahead rye. This annual grass is invading the Western United States, where it displaces native grasses and fuels wildfires that destroy the re-establishment of sage grouse habitat. The invasive plant endophyte culture collection will serve as a critical resource for studying symbiotic

interactions that drive plant invasions and support research for developing environmentally sound weed control strategies.

**New attractant for the shot hole borer, an invasive tree pest.**

The shot hole borer transmits *Fusarium* dieback, a serious plant disease affecting the California avocado industry. The shot hole borer was first detected in Florida groves in 2012, and increasing populations have resulted in tree damage comparable to damage in California. While conducting research on attractants for red ambrosia beetles in avocado groves, ARS scientists in Miami, FL, discovered that a-copaene attracts the shot hole borer. Further research determined that a-copaene and quercivorol, a current shot hole borer lure, are equally as attractive to the insect and that a combination of the two chemicals results in significantly higher beetle capture. ARS scientists and collaborators are using the new lure in Miami-Dade County avocado production areas to determine the prevalence of this new pest. Researchers will continue to evaluate the efficacy and longevity of this new two-component lure for shot hole borer.

**Fruit fly control allows Hawaii to export Sharwil avocados.**

Sharwil avocados produced in Hawaii are known for their large size and buttery taste, but have been banned from entry into the U.S. mainland since 1992 after a fruit fly species was found in an outbound shipment. Since that discovery, the U.S. per capita consumption of avocados has increased nearly sevenfold, outpacing mainland production levels. Hawaiian avocados can still be shipped if they go through a fumigation process, but that can affect taste. ARS scientists in Hilo, HI, developed a systems approach for fruit fly control in avocados that has been approved by the USDA Animal and Plant Health

Inspection Service as an export protocol. The first shipment of Hawaiian Sharwil avocados in 25 years was made this year and several growers are planting new avocado orchards to take advantage of the export program. This pest control system will help increase U.S. contributions to domestic demand for avocados and support avocado production in Hawaii.

### **Genome of the lesser grain borer sequenced and annotated.**

The lesser grain borer, an insect pest of stored grain, is difficult to control because it has immature stages that feed internally in grain. Grain borer populations are also becoming resistant to many commonly used control methods, including phosphine fumigation. Genome sequence information provides information about genetic roles in basic biological functions in insects, including insecticide resistance, but a sequenced genome is only available for one grain pest, the red flour beetle. ARS scientists in Manhattan, KS, used data from short-read sequencing platforms (Ion Torrent PGM, Illumina Mi-Seq) and long-read platforms (PacBio) to sequence the genome of the lesser grain borer. They have compiled a draft genome and are using sequencing data from phosphine-resistant insects to map resistance genes and identify pathways that contribute to resistance. This work will allow scientists to develop, modify, and improve resistance management strategies for improved efficacy, and develop new probes for monitoring pesticide resistance in the field.

### **Updated Compendium of Fruit Fly Host Information (CoFFHI).**

Fruit flies damage fruits and vegetables through oviposition and larval feeding and restrict commodity transport across national and international borders. Establishing appropriate regulatory procedures requires accurate information on commodities that host fruit fly species. The Compendium of Fruit Fly

Host Information (CoFFHI) provides current, centralized, comprehensive, interactive, and searchable information about fruits and vegetables that are hosts of fruit flies. CoFFHI is available online (<https://coffhi.cphst.org/>) and was developed through collaborative efforts of ARS scientists in Hilo, Hawaii; the USDA Animal and Plant Health Inspection Service (APHIS); the Center for Plant Health Science and Technology (APHIS-CPHST); and the Center for Integrated Pest Management. It contains comprehensive documentation of host records for the Mediterranean fruit fly, the carambola fruit fly, the guava fruit fly, and *Bactrocera latifrons*, as well as updated host lists for the oriental fruit fly and the melon fly. CoFFHI can be used by scientists and regulatory officials to assess and mitigate risk of importing fresh horticultural commodities that might result in the introduction and establishment of exotic fruit flies that would threaten U.S. agriculture and natural resources. It also serves as a decision tool that USDA and various State regulatory agencies can use to design and implement effective fruit fly detection, monitoring, suppression, and eradication programs.

#### **New bio-based weed inhibitors found in toothpick weed.**

Plants constitute a rich source of novel and diverse compounds that potentially could be effective and environmentally safe herbicides. ARS scientists in Oxford, MS, found two highly phytotoxic compounds, khellin and visnagin, in toothpick weed. In laboratory tests, these compounds inhibited the growth of lettuce, duckweed, weedy ryegrass, morning glory, foxtail, and weedy millet, and equaled or exceeded the effectiveness of the commercial herbicides acetochlor and glyphosate. In greenhouse tests, visnagin was also very effective against velvetleaf, crabgrass, and barnyardgrass. These findings indicate that visnagin, and possibly khellin, are good candidates for further development into bioherbicides or as lead molecules for the development of new herbicides.

**Nitric oxide fumigation treatment for control of light brown apple moth.**

Most countries have imposed a quarantine on fruit imports that might introduce light brown apple moth, which is a pest of U.S. apples. Effective treatment is needed to facilitate exports of U.S. fresh produce to these countries. An ARS researcher in Salinas, CA, successfully controlled light brown apple moth with nitric oxide fumigation. Under ultralow oxygen conditions, this treatment achieved complete control of light brown apple moth eggs, larvae, and pupae at a low cold storage temperature in 6 to 48 hours, depending on nitric oxide concentrations. The study demonstrates the great potential of nitric oxide fumigation in controlling light brown apple moth and other postharvest pests on exported fresh products, which could create new international markets for apple exports.

**New technology ensures compliance with maximum residue levels for export crops.**

The export of California tree nuts to the European Union has an estimated value of \$2.5 billion annually. An ARS scientist in Parlier, CA, developed novel analytical methodologies to measure and reduce pesticide residue levels on tree nuts to comply with the maximum residue levels allowed by the European Union for almonds and walnuts. These methodologies included the use of gas chromatography-mass spectrometry to quantify phosphorous acid residues, as well as a new method that quantifies residues of propylene oxide and associated chemical compounds. The transfer of this method to European Union chemists and regulators resulted in the establishment of temporary phosphorous acid maximum residue levels for tree nuts through March 2019, which allows the export of California tree nuts until a permanent import tolerance can be established. This research also provides a key base for technical interaction between the California tree nut industry, the USDA Foreign Agricultural Service, the USDA Animal and Plant Health Inspection Service, the U.S. Environmental Protection Agency, and

respective counterparts in foreign governments, with the ultimate goal of protecting export markets and supporting U.S. agricultural producers.

**Development of a vibration trap and mating disruption systems for Asian citrus psyllids.**

Asian citrus psyllids (ACP) are invasive insect pests that transmit the bacterium responsible for citrus greening, a serious threat to the Florida citrus industry. Unlike most insects, male and female ACP use wing-buzzing vibrations instead of pheromones to locate and court one another in citrus trees. ARS researchers in Gainesville, FL, developed and tested a highly efficient device that mimics courtship vibrations produced by ACP females to trap ACP males and have used vibrational signals that mimic ACP females to disrupt mating. Devices are being engineered for the transfer of this technology to field environments to improve ACP detection and control to help protect the Florida citrus industry from additional economic losses.

**Effective delivery of a novel pest control compound.**

Insect pests have developed resistance to several conventional pesticides, and new approaches that target critical life processes are needed for pest management. Although neuropeptides act as potent messengers to regulate vital insect functions, the neuropeptides themselves hold little promise as pest control agents because they can be degraded in the target pest and cannot efficiently penetrate insect exoskeletons. ARS researchers in College Station, TX, and collaborators developed “Diapause Hormone” neuropeptides that, for the first time, penetrate the outer barrier of pupae of many moths. After penetration, these neuropeptides prevent insects from entering the protective state of diapause, which is a dormant state widely exploited by insects to circumvent winter and other adverse seasons.

The insects eventually die because they are unable to enter diapause. This work represents a major breakthrough in the development of a new, practical, and environmentally friendly strategy based on neuropeptide-like substances for control of pest insects via diapause disruption. The findings could help entomologists develop cost-effective controls producers can use to prevent and control losses from moth pests.

### **Discovery of a new emerald ash borer biocontrol agent.**

The emerald ash borer (EAB) is a serious invasive forest pest from northeast Asia that has killed hundreds of millions of ash trees since its 2002 discovery in Michigan. It is now found in 27 U.S. States. The only viable option for effective long-term EAB management in North America may be classical biocontrol via the introduction of co-evolved natural enemies from the pest's native range. ARS researchers in Newark, DE, discovered and described a new species of EAB egg parasite previously collected from the Russian Far East. This species, which is new to science, is described as *Oobius primorskyensis*. Its reproductive biology and progeny dormancy patterns appear distinctively different from the patterns of *O. agrili*, a previously introduced EAB egg parasite, and it may be a more suitable EAB biocontrol in the northeast United States. *Oobius primorskyensis* is currently being evaluated by the USDA Animal and Plant Health Inspection Service for environmental release as a biocontrol agent that might help improve the efficacy of the current EAB biocontrol programs, which would add needed support to the survival and recovery of North American ash trees.

**Identified tolerance to *Prunus* replant disease in rootstocks for almond and other stone fruits.**

Cultivated species of *Prunus*, including almonds, peaches, and other stone fruits, cover more than a million acres in California alone, and the orchards must be replanted every 15 to 25 years to remain economically viable. Preplant soil fumigation is practiced widely among replanted orchards to control *Prunus* replant disease (PRD), which is caused by a soilborne microbial complex that suppresses plant growth. ARS scientists in Davis, CA, conducted replant trials to identify rootstocks with tolerance to PRD and found that all 20 rootstock selections were affected by PRD. However, peach/almond hybrid rootstocks were impacted much less severely than peach rootstocks. Although peach/almond hybrid rootstocks are not appropriate for poorly drained soils or soils infested with certain plant parasitic nematodes, their use may reduce the need for preplant fumigation in well-drained soils impacted only by PRD. These findings could help specialty crop producers optimize the selection and cultivation of stone fruit replacement trees.

**Mediterranean fruit fly genome sequencing, assembly, and annotation completed.**

The Mediterranean fruit fly (Med Fly) is one of the most serious threats to agriculture in the United States and around the world. ARS researchers in Gainesville, FL, and Hilo, HI, and collaborators sequenced and annotated the Med Fly genome to learn more about genetic pathways essential to development, behavior, and reproduction. They identified specific genetic expansions that can be related to invasiveness and host adaptation, including chemoreception, toxin and metabolism, immunity, and cuticular proteins. This new knowledge will provide new genetic tools and advanced technologies for controlling medfly populations, such as new tools to enhance control by the sterile insect technique (SIT), which will help producers control MedFly infestations and reduce production losses.

### **Biological control for spotted wing drosophila.**

Organic growers and other producers need non-toxic insecticides to control the spotted wing drosophila (SWD), a pest of small fruit and tree fruit crops. ARS scientists in Corvallis, OR, found that the non-nutritive sweeteners erythritol and erythrose have insecticidal effects against SWD adults in laboratory studies. These artificial sweeteners were dissolved in water and fed to SWD adults, which resulted in more than 60 percent mortality within 4 days. These findings indicate that these sweeteners have potential as organic insecticides and may provide organic growers with new options for controlling SWD.

### **Pesticide residue levels in specialty food crops and ornamental plants.**

The Interregional Research Project Number 4 (IR-4) is the primary U.S. entity for facilitating the registration of conventional pesticides and biopesticides for specialty food crops and non-food ornamental horticulture crops. ARS researchers in Wapato, WA, in collaboration with IR-4 personnel at Rutgers University, NJ, tested new pesticides on 10 food crops and evaluated pesticide residues and efficacy against pests. These pesticides were also tested on 12 ornamentals to evaluate crop safety. Most of the food crop pesticide residues were below the minimum levels deemed safe by the U.S. Environmental Protection Agency (EPA), indicating they can safely be used on specialty crops. This information will be submitted to EPA by the IR-4 Project to enable the registration of pesticides needed to protect specialty food crops and ornamental plants from insect pests and give producers another tool for managing pest infestations.

**Hairy vetch and cereal rye cover crop mixtures improve nutrient management and weed suppression.**

Legume cover crops provide nitrogen to subsequent cash crops, while grasses provide good weed control and scavenge soil nitrogen, but more information is needed about how soil and crop management practices (fertilizer and tillage) affect cover crop decomposition. At two locations over 2 years, ARS researchers in Beltsville, MD, evaluated how seeding rates, tillage, and poultry litter applications (broadcast versus subsurface banded) influenced cover crop decomposition. The researchers found that maximum residue persistence is achieved using a pure cereal rye cover crop combined with either no poultry litter or subsurface banded poultry litter. Pure hairy vetch residue released the most nitrogen, particularly when incorporated with poultry litter, but incorporation also increased the rate of nitrogen release, which reduced its availability to corn cash crops when needed. These results will be used to develop Web-based decision-support tools for developing optimal nitrogen management strategies that can help farmers decide how to use cover crop mixtures.

**An inexpensive attractant dispenser system for codling moth mass trapping.**

Codling moth is a key pest of apple, pear, and walnuts in the United States and other countries. New approaches and technologies, such as using female moth lures for mass trapping, are needed to replace pesticide applications and to augment mating disruption systems that are widely used. ARS scientists in Wapato, WA, developed an inexpensive sachet system as a lure for female and male codling moths that provides optimized controlled release of acetic acid, a fruit volatile, and pear ester. Field tests validated the attractiveness and performance of the new dispenser system as a lure for traps. Previous and parallel

research demonstrated control of codling moth damage with 50 baited traps per acre, and reduced costs for lures and traps will benefit growers adopting this approach. These developments show promise as new technologies for the control of codling moth by conventional and organic fruit growers.

### **Improved weed management in sugar beet grown for biofuel.**

Sugar beets grown for biofuel are being considered as an alternate cool-season crop in the southeastern U.S. coastal plain. Cost-effective weed control is needed to make this alternative cropping system feasible, and current herbicides registered for use on sugar beet are costly. ARS researchers in Tifton, GA, effectively controlled cutleaf evening primrose, the most troublesome weed of sugar beet, and reduced application rates of the herbicides phenmedipham plus desmedipham. This integrated approach to managing weeds provided adequate weed control, protected sugar beet yields, and reduced costs by more than 30 percent. This unique cropping system will give growers an option to produce another second annual crop during the winter growing season in the southeastern United States, which could increase overall producer profits.

### **Fungicide inhibits cellular respiration in honey bees.**

Honey bees and other pollinators often are exposed to fungicides that are applied to plants in bloom where bees are collecting nectar and pollen. Fungicides control fungal growth on the plant by inhibiting basic cellular functions that are shared among broad ranges of organisms. Specifically, the fungicide Pristine prevents fungal growth by inhibiting cellular respiration and reducing the production of adenosine triphosphate (ATP), a molecule that animals use to convert food into energy. ARS

researchers in Tucson, AZ, found that field-relevant concentrations of Pristine fed to honey bees in pollen inhibited ATP production. Lower bee ATP levels could explain previously reported effects of Pristine on protein digestion and immunity in honey bees since ATP is essential in metabolic pathways associated with these physiological processes. The effect of Pristine in honey bees indicates that this fungicide might not be safe for pollinators when applied where bees are foraging.

**Newly developed medium for the cryopreservation of bee semen.**

Increasingly, cryopreserved bee semen (stored in liquid nitrogen for indefinite storage) is used to inseminate queen bees. Although semen transferred during mating (i.e., non-cryopreserved semen) lasts for the lifetime of a naturally fertilized queen, cryopreserved semen is not stable. A dilution medium for bee semen developed by ARS scientists in Fargo, ND, was converted into a cryoprotective medium with the addition of an antifreeze (dimethyl sulphoxide). With the newly designed cryoprotective medium, the scientists were able to obtain viable bee sperm cells with an average viability of more than 94 percent. This is a significant advancement in the field of semen cryobiology and will form the foundation for ensuring preservation of this vital agricultural resource at the National Bee Gene Bank in Fort Collins, CO.

**Patent issued for bee attractant to increase blue orchard bee nesting and production.**

The decline of honey bee colonies throughout the United States has increased the need for identifying other bee pollinators. Although the blue orchard bee can be used for managed pollination of many nut and fruit crops, one major hurdle to their use has been getting the bees to nest reliably within orchards.

ARS scientists in Logan, UT, and Fargo, ND, with their commercial partners, developed and patented an attractant (Patent # US9301521) for the blue orchard bee that has been shown to be effective in increasing the numbers of bees available for pollination when sprayed on orchard nesting boxes. The researchers are working with their partners to commercialize a product for use by beekeepers.

**Almond yield increased by pollinating with blue orchard bees and honey bees.**

Almond yields are largely dependent on effective pollination of trees by bees. ARS scientists from Logan, UT, working in California, evaluated the use of both blue orchard bees and honey bees for increasing almond yields when compared to just using honeybees. Results from 2 years of trials demonstrated that using blue orchard bees along with honey bees increased almond fruit set (average fruit set 67 percent) compared to use of only honey bees (average fruit set 30 percent). Overall nut yield was increased in many of the plots with both blue orchard bees and honey bees. These results indicate there are potential benefits to using blue orchard bees in both maximizing orchard yields and helping to decrease the demands on honey bees.

**Bee foragers may be bringing Varroa mites into bee hives.**

The varroa mite is a serious pest of honey bees and may be the leading cause of colony losses. Varroa mites have relatively low reproductive rates, so populations should not increase rapidly, but often they do. ARS researchers in Tucson, AZ, determined that mites can enter colonies on foraging bees and significantly increase varroa populations to levels many times greater than from mite reproduction alone. Mites entering colonies on foragers most frequently in the late summer or fall when colonies are

preparing to overwinter, which suggests the influx of mites on foragers could be a major cause of overwintering losses. These results indicate that additional mite sampling and varroa treatments may be needed as long as bee foraging activity occurs in the fall.

### **A new manageable bee pollinator for the southeastern United States.**

Obtaining strong commercial colonies of honey bees for crop pollination is becoming increasingly difficult and expected to detrimentally affect sustainable U.S. food production unless alternative pollinators become available. ARS researchers in Poplarville and Stoneville, MS, and Logan, UT, tracked the spread of an accidentally introduced bee from Asia. The bee, commonly known as the giant resin bee, visits many exotic trees growing in the southeastern United States where this bee uses dilapidated wooden structures for nesting. The researchers discovered giant resin bees readily nested in cardboard bee nesting tubes intended for gathering blue orchard bees. These observations indicate that the giant resin bee might be a viable candidate for inclusion on the growing list of manageable native bee crop pollinators for use in American agriculture.

### **Survey of queen bumble bee pathogens reveals potential causes of colony loss.**

Bumble bee colonies depend on healthy solitary queens to establish nests in the spring of each year. In commercial colonies used for greenhouse pollination, increased losses are found during production. ARS researchers in Logan, UT, screened more than 300 queen bumble bees from 6 States for parasites and pathogens. Among the pathogens, the most prevalent was a protozoan *Crithidia bombi*, which causes low-nesting success in queen bumble bees, and four viruses, with black queen cell virus found in 19 percent of all the individuals. Also notable was the presence of a queen-castrating nematode in 7

percent of the queens. These results provide quantitative evidence that commercial bumble bee producers need to improve their methods of screening for, and treating, bumble bee pathogens in rearing operations.

### **Preventative management of grapevine trunk diseases.**

Advisors on grape pest control efforts recommend preventative practices for vine trunk diseases beginning in the early stages of vineyard growth. While these practices may be most effective long-term when used in young healthy vineyards, more often they are applied only in mature, diseased vineyards. The growers' preference for application of these practices later in the growth cycle demonstrates a knowledge gap between published research and farming practices. ARS scientists in Davis, CA surveyed growers and found that most growers do not adopt preventative practices until after symptoms are widespread. The scientists calculated the economic impacts of adopting preventative practices in young vineyards that clearly showed financial benefits of proper timing of treatment before symptoms are widespread. The results were communicated to growers through new online management plans and a Web site where growers can compare the returns expected under different preventative practices. These findings illustrate the advantages of taking advantage of recommended disease management practices in vineyards.

### **Improved management of greenhouse gas emissions for the wine-grape industry.**

It is well known that agricultural land contributes to global emissions of greenhouse gases (GHG), but it is poorly understood how different crops and management practices contribute to those emissions. ARS researchers in Davis, CA, demonstrated that nitrous oxide emissions from vineyards subjected to diverse

management practices were greatest in response to the first precipitation event of the rainy season in California's Mediterranean climate. In the dry season, large nitrous oxide fluxes were related to drip irrigation and fertigation practices, indicating that modifications to such practices may reduce gaseous emissions. The researchers also demonstrated that GHG emissions were limited by soil water availability rather than soil temperature. This study provided valuable data that were used by the USDA Natural Resources Conservation Service to develop COMET-Farm, a practice-based tool to assess GHG footprints. This information gives growers practical guidelines on how they can reduce GHG emissions.

**Foliar application of a plant hormone increases grapevine cold hardiness.**

Wine grapevines of European origin (*Vitis vinifera*) are often injured or killed by cold weather events in autumn, mid-winter, and spring. An ARS scientist in Parma, ID, in cooperation with Canadian collaborators and collaborators at Washington and Ohio State Universities, identified concentrations, application timings, and formulations of the plant hormone abscisic acid that increased bud cold hardiness in the wine grape cultivars Chardonnay and Merlot. Foliar application of a naturally occurring form of abscisic acid advanced the onset of dormancy and increased bud cold hardiness in autumn. Foliar application of a long-lived analogue of abscisic acid increased bud cold hardiness and delayed bud break in the spring following application and was most effective when applied after harvest. Wine grape producers are using these findings to improve the cold hardiness of their grapevines and reduce economic losses due to cold injury.

### **Improving drought stress in plants.**

Drought is one of the major environmental stresses constraining agricultural production. Plants have evolved diverse strategies to respond to drought, including increasing production of the hormone abscisic acid (ABA). An ARS researcher in Davis, CA, in collaboration with researchers at the University of California, Davis, has produced transgenic petunias that increase ABA concentrations when exposed to drought stress. The plants were not only resistant to severe drought, but fully recovered when water stress was lifted. Additionally, these plants grew like traditional petunias in the absence of drought stress. These results demonstrate an example of the successful modification of plants to improve drought tolerance, an approach that could be useful when applied to improve drought resistance in other crops.

### **Use of winery wastewater for irrigation in California vineyards.**

The scarcity of water in California is compelling growers to identify new water sources for irrigating crops. ARS researchers in Davis, CA, demonstrated that municipal wastewater treatment produced water acceptable for irrigating grapes. The treated water also did not increase soil salinity, which is a major problem for agriculture in California. Irrigating grapes with treated water did not have any perceived effects on wine sensory characteristics. Wineries and vineyard operators will need to ensure their treated wastewater will have acceptable quality for irrigation. Reuse of wastewater provides a way to produce grapes of high quality that will sustain and enhance the wine industry of California while supporting conservation of limited freshwater resources.

**Reducing irrigation after harvest is safe for blackberries and saves water.**

Small fruit growers are facing serious water limitations due to warmer and drier weather conditions, increased regulations, and greater demands for water by other sectors. Last year alone, the small fruit industry lost an estimated \$20 million of fruit in the Pacific Northwest due to heat and inadequate supplies of water for irrigation and cooling. ARS scientists in Corvallis, OR, in collaboration with scientists at Oregon State University, found that growers could safely stop irrigating their blackberry fields after harvest. Withholding irrigation after harvest has no subsequent effect on yield or fruit quality of blackberry, which is a perennial crop, but can save growers 67,000 gallons of water per acre each year. The strategy also helps the plants to harden off in the fall and reduces the potential for freeze damage to the crop over the winter. These findings provide growers with a new approach to water management that considerably reduces production costs and improves stewardship of limited water resources.

**Improving spray application in pecan tree canopies.**

Effective coverage of tree canopies by fungicide sprays is required for efficient disease control. However, it was not clear how tractor speed and spray volume affected the coverage of sprays on tree canopies. ARS researchers at Byron, GA, showed that slower tractor speeds and the use of volutes, which increase the pressure of the spray application, improved spray coverage at greater heights in the canopy. These results demonstrate an improved method for selecting appropriate application volumes and speeds when applying pesticides to maximize canopy coverage for improving disease control.

**High-yielding drought-tolerant soybean cultivar.**

Drought is a major problem for many crops, but has not been thoroughly addressed in soybean research. Drought-resistant soybean cultivars are virtually non-existent in the United States, and the first drought-resistant Asian soybean accession from the USDA National Plant Germplasm System (NPGS) was reported only in 1989. ARS researchers in Raleigh, NC, using classical breeding methods, have incorporated drought resistance traits from the Asian accession into a new high-yielding cultivar 'USDA-N8002'. The newly released cultivar exhibits slow or delayed canopy-wilting, sustained nitrogen fixation during drought stress, and a water-conserving transpiration response when exposed to atmospheric vapor pressure deficit conditions. It has very stable yields over the Southeast United States in both full season and double-cropping production. This new cultivar is available for production and for use as parental stock for commercial breeding programs aimed at breeding drought resistance into soybean cultivars. The release was featured in the Crop Science Society of America news magazine, CSA News.

**Reduced-allergen wheat.**

Wheat flour is one of eight foods responsible for 90 percent of food allergies in the United States. ARS scientists in Albany, CA, created transgenic wheat lines in which the omega-5 gliadins, the major sensitizing allergens in a severe food allergy called wheat-dependent exercise-induced anaphylaxis (WDEIA), were significantly reduced in the flour without adverse effects on flour quality. In collaboration with scientists at the French National Institute for Agricultural Research (INRA), the allergenic potential of these lines was evaluated using sera from a collection of WDEIA patients. Most patients showed little or no reactivity to omega-5 gliadins in the transgenic lines, indicating that the

transgenic lines could be considered reduced-allergen. However, low levels of reactivity with other gluten proteins were also observed with the transgenic lines. While flour from the transgenic lines would not be suitable for individuals diagnosed with WDEIA, introduction of wheat lacking omega-5 gliadins could reduce the number of consumers who become sensitized to these proteins and decrease the overall incidence of this food allergy.

### **Release of high-phytonutrient potato varieties.**

Health professionals and consumers are placing increased importance on the nutritional value of foods, a key component of food security. Consumers are also increasingly demanding that their food be produced using less agrochemicals, which is problematic for potato producers since they commonly have to apply fungicides throughout the growing season to control diseases. Potatoes are nutritionally dense crops that are very low in fat, while being rich sources of protein, fiber, anti-oxidants, minerals, and calories. ARS scientists in Prosser, WA, working with collaborators in the TriState Breeding Program, released two new high-phytonutrient potato varieties. ‘Yukon Nugget’ and ‘Smilin’ Eyes’ are yellow flesh potato varieties that have higher yields, improved disease resistance, and greater anti-oxidant concentrations than ‘Yukon Gold’, the standard commercial yellow flesh potato variety. These new varieties enable growers to produce potatoes that require fewer applications of chemicals to control disease and meet evolving consumer preferences for nutritional foods.

### **Durable sunflower rust and downy mildew resistance.**

Rust and downy mildew are two of the most devastating diseases of sunflower. In the United States, oilseed sunflower is challenged by a serious foliar leaf rust disease that has been increasingly prevalent

in much of the production region, with rapid development of new virulent races. Very few suitable sunflower inbred lines with high levels of rust resistance are available to commercial sunflower breeders. ARS scientists in Fargo, ND, developed and released a sunflower germplasm resistant to both rust and downy mildew that was derived from the annual crop wild relative of sunflower. The stacking of these genes in one germplasm incorporates dominant genes with resistance to all known races of North American sunflower rust and all known races of the pathogen causing downy mildew. The molecular markers relating to both of these genes have been provided to the sunflower industry to allow breeders to develop additional varieties with resistance to multiple pathogens, thus assuring sustainable sunflower production in the presence of two devastating diseases.

#### **Sequencing the carrot genome.**

Carrots are nutritionally dense vegetables that are rich sources of fiber, anti-oxidants, and minerals. However, carrot producers in the United States suffer millions of dollars of losses annually due to pathogenic nematodes. The development of improved carrot varieties has been impeded by a lack of understanding of the carrot genome. ARS scientists in Madison, WI, led an effort involving 20 scientists from seven countries that sequenced the carrot genome. The researchers identified genes involved in nematode resistance, resistance to environmental stresses, and the production and accumulation of phytonutrients. The research significantly advanced our understanding of the genetic control of orange and yellow pigment development and the genetic control of important traits that breeders will be able to use to accelerate the development of carrot varieties with enhanced disease resistance and improved nutritional qualities. This information will also be used to identify gaps in the U.S. national carrot germplasm collection that require filling.

**New genomics-powered database tools address breeder needs for maize (corn) and rice.**

The data generated by U.S. maize and rice geneticists are expanding rapidly, as is the demand for bioinformatic tools that enable researchers and breeders to utilize this knowledge. ARS scientists in Ames, IA, and Stuttgart, AR, developed three new bioinformatic tools to accelerate maize and rice breeding and research. First, the MaizeGDB Genotype Visualization Tool enables maize researchers to survey the genomes of 17,000 maize lines and display all DNA differences in any region of their respective genomes. The MaizeGDB Pedigree Viewer enables breeders to visualize pedigree relationships between maize germplasm lines and identify the best lines genetically as parents for crossing. Combined with knowledge of maize genome functional variation in MaizeGDB, these tools enable breeders to select maize lines to cross to improve germplasm for researchers and farmers. For rice breeders, ARS scientists in Stuttgart, AR, created Ricebase, a new database that integrates rice genetic variation, pedigrees, and whole-genome-based data, thus accelerating the discovery and design of molecular markers for marker-assisted breeding and selection, thereby enabling rice breeders to accelerate their selections more efficiently. ARS bioinformaticians continue to develop powerful new tools that enable maize and rice researchers to leverage USDA's open germplasm, data, and information for crop improvement

**New soft white winter club wheat cultivar 'Pritchett' released.**

The club wheat market class represents approximately 8 percent of the total wheat production in the Pacific Northwest region of the United States, but there are no private or other public-sector research programs developing club wheat. Club wheat is characterized by its compact head and is exported to Asian markets, where it is highly valued as a main ingredient of sponge cakes. Existing club wheat

cultivars either do not emerge well from deep sowing in dry conditions; are susceptible to preharvest sprouting; or suffer from lower quality at harvest. ARS researchers in Pullman, WA, in collaboration with wheat breeders from Washington State University, developed and released a new winter club wheat cultivar, 'Pritchett'. The new cultivar has generated excitement among growers in the drier areas of the club wheat production zone because it has excellent emergence from deep sowing and can be grown with reduced fungicide inputs because it is resistant to stripe rust and cephalosporium stripe, and is moderately resistant to eyespot. Additionally, 'Pritchett' possesses better milling and baking quality than the current standard variety, 'Bruehl'.

#### **Successful implementation of reverse genetics in soybean.**

Reverse genetics is the process of discovering the biological function of a gene by modifying or deleting it, then determining what effect the change has on the organism. While gene and RNA sequencing technologies have become routine and inexpensive, there are still many unanswered questions about how genes function. Simply knowing a gene's function, however, does not translate into useful products, such as improved soybean germplasm, without a way to easily identify usefulness of the genetic variants resulting from the change. ARS researchers in West Lafayette, IN, and collaborators implemented a method to use high-throughput DNA sequencing to identify variants in any gene from large soybean mutant populations. As part of this work, the researchers discovered a non-functional variant of a gene involved in carbohydrate biosynthesis in soybean seeds. Elimination of this gene resulted in soybean meal that humans and other monogastric animals (pigs and poultry) can digest. This variant creates a more functional soybean meal for food and feed. It is being evaluated in genetic crosses for its impact on carbohydrate composition, and will be useful to soybean breeders for improving soybean meal.

**Release of high-yielding and disease-resistant sugarcane varieties.**

The biggest production challenges faced by sugarcane growers in Florida are orange rust and brown rust diseases, which reduce yields and increase production costs because of the need to apply fungicides for disease control. Consequently, the development of new sugarcane varieties with enhanced disease resistance is a priority for increasing crop yields and economic returns. ARS researchers in Canal Point, FL, collaborated with other researchers and released eight new high-yielding sugarcane varieties that are especially adapted to the sandy soils in Florida and have improved resistance to rust diseases. The new cultivars produce high yields while reducing production costs, which results in higher grower profits and supports the economic viability of sugarcane production in Florida.

**Identification of lettuce and spinach varieties with tolerance to heat, drought, and salinity.**

Global warming and climate change pose serious threats to U.S. agriculture and food security. Consequently, the development of crops that can cope with heat, drought, and other environmental stresses may well be the single most important step that can be taken to assure food security under changing environmental conditions. ARS researchers in Salinas, CA, screened about 4,000 lettuce and 400 spinach varieties in greenhouse tests and field trials, and identified varieties with tolerance to heat, drought, and salinity. The identification of these varieties is useful to growers producing lettuce and spinach in areas that are prone to these stresses and for breeders trying to develop new vegetable varieties with enhanced resistance to environmental stresses. These varieties will also help expand the growing seasons for lettuce and spinach in areas where land costs tend to be lower than traditional lettuce and spinach growing areas, such as the San Joaquin, Yuma, and Imperial Valleys of the southwest United States.

**‘Kardia’, a new food barley cultivar.**

Increasing the levels of grain beta-glucan in barley is desirable as it is associated with cardiovascular health. Barley bred and grown specifically for food use has therefore received more attention in recent years. The food barley cultivar ‘Kardia’, developed by ARS researchers in Aberdeen, ID, has 40 percent higher grain beta-glucan and better grain yield than the current industry standard cultivar, ‘Salute’. This combination of characteristics can increase the efficiency of producing food-grade, high-beta-glucan barley, which will increase producer and processor profitability and increase availability of highly nutritional food for consumers. ‘Kardia’ is being marketed to the food industry as a barley ingredient for their national and international products.

**Maize genetic variation is determined by 2 percent of the genome.**

Maize is the number-one crop grown in the United States. The maize genome is large and complex, so determining what portion of the genome has effects on traits has been challenging. ARS researchers in Ithaca, NY, along with university collaborators, assayed maize to identify the portions of the DNA sequence accessible to proteins that regulate gene expression. Then, using quantitative genetics, the researchers determined that 2 percent of the maize genome was controlling most of the field variation. Approximately half of the measured genetic variation could be explained by regions of the genome accessible to gene regulators. This finding and method for identification of functional field variation is a general approach that can be applied to all plants and has the potential to accelerate the breeding of crops because it reduces the regions of the genome that would have to be examined.

### **Genomes of two wild peanut cultivars sequenced.**

A crop reference genome sequence is the foundation for accelerating modern crop breeding and genetic studies. ARS scientists in Stoneville, MS, Ames, IA, and Tifton, GA, along with their partners, sequenced the genomes of two wild relatives of cultivated peanut whose ancestors merged to form a new species, which was then domesticated to become the modern cultivated peanut. An important finding of this research is that the unusual hybridization of these two species was likely the direct result of early agriculturalists in South America. The genome sequences from these wild species thus comprise essentially all of the genetic material in the modern cultivated peanut. This research will provide the foundation for plant researchers and breeders to more efficiently select for improved peanut varieties and to speed development of varieties better suited for growing in various regions of the world. The genome sequence has already been used to help identify mechanisms for resistance to root-knot nematodes and rust (a fungal disease), serious challenges for many peanut farmers.

### **Genetic markers identified for accelerating lentil genetic improvement.**

U.S. lentil production has increased more than 20 percent in recent years because of high export demand and recognition of the lentil's health-promoting qualities. But little information has been available to breeders about the genetic diversity in this crop and its association with ecological adaptation. ARS researchers in Pullman, WA, and their international cooperators, used approximately 1,000 genetic markers to analyze more than 300 genebank samples from diverse locales to identify specific agroecological zones containing a large amount of lentil genetic diversity. The findings yielded information valuable to breeders for selecting superior breeding stock to increase yield and product quality to meet the U.S. domestic and international market demands.

**New citrus rootstock with tolerance to citrus greening is released.**

*Huanglongbing* disease, also known as citrus greening, is the most economically destructive disease of citrus crops in the world. The disease has spread to all citrus production regions of the United States and has reduced orange yields in Florida alone by more than 40 percent. No varieties of citrus have been found with resistance to the disease, and no other methods have been identified for effectively controlling the disease. ARS researchers in Fort Pierce, FL, identified and released a new citrus rootstock, 'US-1516', that promotes better tree health and produces higher orange yields than other commercial rootstocks when grown in the Florida central ridge area, which is severely affected by citrus greening. Rootstock 'US-1516' provides growers with an important tool to manage citrus greening and help provide for the continued production of citrus in the United States.

**A rapid method to identify boxwood plants with resistance to blight disease.**

Each year, more than 13 million boxwood plants are sold in the United States, making boxwood one of the most popular shrubs in the American landscape. A new blight disease, caused by the fungus *Calonectria pseudonaviculata*, is causing devastating losses to boxwood throughout the northeast and mid-Atlantic United States. Developing disease-resistant cultivars of boxwood is the only long-term sustainable solution to this problem, but it has been difficult to rapidly identify plants with this trait. ARS scientists at the U.S. National Arboretum in Washington, D.C., developed a method using detached leaves to quickly and effectively screen boxwood for blight resistance. The screening method, which was published in the peer-reviewed journal *Plant Disease*, is being used by plant breeders to quickly identify plants with disease resistance. Resistant plants can then be used as parents to develop new

boxwood varieties with improved blight resistance, which reduces losses to nurseries and the landscape of the eastern United States.

**Assessing the loss of crop genetic diversity through historical records.**

The popular press periodically cites as evidence of crop genetic diversity loss that fewer named crop varieties are available now when compared to the past. ARS researchers in Fort Collins, CO, assessed the importance of historical U.S. apple cultivars based on how frequently they were mentioned in historical records, such as seed catalogs and county fair notices, during the period of 1736 to 1909. The researchers determined that nearly 70 percent of the important historic U.S. apple cultivars and their constituent genes are currently conserved in the ARS National Plant Germplasm System genebank and that an additional 20 percent are available from other collections. Thus, the first application of this new method demonstrated that most of the key U.S. historic apple cultivars are currently available. This method also provides a valuable tool for identifying specific cultivars to safeguard in genebank collections, making additional genetic diversity available to producers, researchers, and breeders to enhance global food security.

**Using marker-assisted selection to improve ginning efficiency in cotton.**

To remain competitive with synthetic fabrics, U.S. cotton growers need to save on production and processing costs wherever possible. It was previously discovered that cotton cultivars differ in how strongly fibers are attached to the seed, and cultivars with reduced fiber-seed attachment force, gin faster with less energy and fiber damage. ARS researchers in Stoneville, MS, identified cotton cultivars with lower net ginning energy (NGE) requirements and discovered an association between the NGE trait and

fuzz percent (FZP), which estimates the amount of fiber remaining on the seed after ginning. With an ability to quickly and accurately identify cotton lines with lower ginning energy requirements, breeders can develop cultivars that save energy at the gin and provide varieties with fiber less prone to damage, as longer, unbroken fiber is highly desired by textile mills.

### **Markers for accelerating pineapple genetic improvement.**

Pineapple, one of the most valuable crops grown in Hawaii, is also the third most important tropical fruit crop globally. Pineapple production in Hawaii and internationally is continually threatened by diseases, pests, and production inefficiencies. Pineapple breeders require estimates of pineapple genetic diversity and access to new horticultural traits to maintain this crop's economic viability. ARS researchers in Hilo, HI, and Beltsville, MD, developed hundreds of new DNA genetic markers that breeders are applying to evaluate pineapple more efficiently for new horticultural traits and to identify the genes governing those traits. The genetic markers improve the efficiency of pineapple genetic resource management at the Hilo genebank by identifying undesired duplicate samples and genetic gaps in the collection that are priorities for future germplasm acquisition.

### **Identifying genes in broccoli responsible for heat tolerance.**

Broccoli is a nutritionally dense food that is a rich source of dietary fiber, protein, minerals, and antioxidants. Unfortunately, high temperatures towards the end of the growing season result in reduced yields and lower nutritional quality of the harvested crop. This susceptibility to high temperatures is the primary factor limiting when and where broccoli can be grown. Poor understanding of the genetic control of heat tolerance has impeded the development of improved broccoli varieties. ARS scientists in

Charleston, SC, identified four genes that account for as much as 60 percent of the differences between broccoli lines for tolerance to high temperatures. Breeders are using this knowledge to search for genes in other broccoli lines to accelerate development of improved varieties that will extend the growing season, expand production areas, and increase resilience to fluctuating climatic conditions.

**Adopting tropical sorghums to temperate zone production.**

Sorghum is an important grain crop in many areas of the United States and other temperate regions worldwide. However, much of the potentially valuable sorghum germplasm is tropical in origin and does not successfully flower and produce seed in temperate environments. ARS researchers in College Station, TX, working with a retired private seed company scientist, used molecular tools with classical plant breeding techniques to convert ARS tropical sorghums to short stature, early flowering versions with the objective of making new elite inbred germplasm available to the sorghum industry. Newly converted sorghum germplasm is being distributed to breeding companies to develop new hybrids.

**New genetic analysis of an important traditional cacao variety from Peru.**

Cacao, the source of chocolate, is a multi-billion dollar international commodity grown by several million small farmers in tropical developing nations of Latin America, Asia, and Africa. Furthermore, U.S. cacao production is expanding in Hawaii and Puerto Rico. Threatened by many virulent diseases, damaging pests, and the effects of climate change, cacao farmers require sturdier trees with inherent resistance to pests and diseases, plus high yields and fine cocoa quality. ARS scientists in Beltsville, MD, and their Peruvian collaborators analyzed the genetic diversity in 'Piura Porcelana', a traditional cacao variety from Peru. They confirmed the genetic uniqueness of this variety, which has a distinct

flavor in demand by high-end international cacao markets. Based on this new genetic information, this variety was collected from the field and safeguarded in Peru's germplasm collection, thereby filling a diversity gap in the cacao germplasm collection.

**Dhurrin, a compound that leads to stay-green sorghum for higher drought tolerance.**

Post-flowering drought tolerance, or stay-green, in sorghum is associated with reduced lodging, charcoal rot resistance, increased grain fill, and increased grain yield. Dhurrin is a cyanogenic glucoside produced by sorghum and is generally considered a natural defense compound capable of producing toxin hydrogen cyanide (HCN) to deter animal herbivory. Recently, ARS scientists from Lubbock, TX, reported that high levels of leaf dhurrin in grain sorghum genotypes was associated with post-flowering drought tolerance (stay-green). Additionally, ARS scientists from Lubbock, TX, genotyped breeding lines varying in leaf dhurrin content showing that DNA sequence differences within the dhurrin biosynthetic genes (CYP79A1, CYP71E1, or UGT85B1) were consistently associated with altered dhurrin content and with stay-green in sorghum. These discoveries will assist sorghum breeders in the development of more drought tolerant sorghum hybrids.

**New genes and enhanced yields from crosses with wild soybean.**

The wild relatives of soybean are a largely untapped resource for soybean breeding, though some breeders have had limited success incorporating their traits into new lines. ARS scientists in Urbana, IL, were successful in using a perennial Glycine species to breed a new soybean line with significantly increased yield. The ARS team completed 2 years of testing of the first soybean experimental lines from crosses with *G. tomentella*, a wild relative used as the female parent, ensuring the resulting progeny

contain *G. tomentella* cytoplasm. An agronomically improved line was recovered with 22 percent higher yields than the adapted soybean parent, and was only 5 days later in maturity. Yield increases of this magnitude over the better parent have not been previously reported in soybean breeding, even when crossing two adapted parents. Additional research is underway to determine the role of *G. tomentella* cytoplasm in this yield increase. This new discovery provides breeders with new yield genes with unique alleles never before used in the North American soybean gene pool.

### **Genetic analysis identifies genes for wax production in sorghum.**

An important feature of sorghum associated with drought tolerance is the presence of wax compounds that cover and protect the stem and underside of leaves. However, there is a lack of genetic information on the genes that underlie wax production in sorghum. ARS researchers in Lubbock, TX, and Cold Spring Harbor, NY, identified two genes that underpin profuse wax or bloom of sorghum. Discovery of genes for waxy bloom will allow the manipulation of the trait to improve drought and heat tolerance in sorghum with implications for other cereal crops. This discovery was highlighted in the Journal, “The Plant Cell.”

### **Improving the soybean genome map.**

The DNA sequence of the soybean genome was published in 2010, and at that time, ARS scientists in Beltsville, MD, provided the genetic map that allowed the segments of DNA sequence to be “anchored” to positions along the 20 soybean chromosomes. Because the number of DNA mapping markers were limited, some of the segments of DNA could not be properly oriented along the soybean chromosomes, and some segments did not contain a DNA marker and therefore could not be positioned in the soybean

genome sequence. Recently, the scientists discovered 37 regions in the 2010 version of the previously published soybean genome sequence where the order of the DNA in the genome sequence needed to be corrected. Furthermore, 28 DNA fragments that could not be determined in 2010 were accurately oriented in the newest version of the soybean genome. The new and improved version of the soybean genome sequence will help breeders identify genes controlling seed yield, seed quality, and resistance to biotic or abiotic stresses.

### **Interspecific sunflower amphiploid genetic stocks.**

Sunflower crop wild relatives include interspecific relatives, containing a large gene pool of 53 different species that possess useful genes needed for maintaining genetic diversity. It is extremely challenging to mine these genes, especially due to incompatibility issues, such as hybridization barriers between cultivated sunflower and the perennial species. Successful hybridization by ARS scientists in Fargo, ND, produced amphidiploids containing a full balanced set of chromosomes from both the crop wild relative and the cultivated sunflower, overcoming common fertility problems often encountered when making wide crosses. The team developed six genetic stocks derived from different wild sunflower species. The value of these interspecific amphiploid genetic stocks is that they can act as a bridge in interspecific gene transfer, allowing for easier backcrossing with the cultivated sunflower to further broaden the genetic diversity of the sunflower crop, as well as to transfer useful target genes for specific traits. The genetic stocks will also allow development of chromosome addition lines containing chromosomes of individual wild species that will be useful in studying the genetics of wild species. These amphiploids give sunflower breeders increased access to more genetic diversity that has been extremely difficult to obtain using traditional breeding methods.

**New stem rust (Ug99) resistant wheat varieties released in Pakistan.**

The globally virulent stem rust race, known as Ug99, can potentially cause significant yield loss and even crop death. New Ug99 stem rust-resistant wheat varieties ‘Borlaug 15,’ ‘Insaf 15,’ ‘Pakhtunkhwa 15,’ ‘Pirsabak 15,’ and ‘Ujala 15’ were developed using Ug99 stem rust resistance genes identified and incorporated by ARS researchers in Raleigh, NC, in collaboration with Pakistani partners. The release of these new Ug99-resistant varieties will provide growers with disease-resistant alternatives for wheat production.

**Release of new sugarbeet breeding line with enhanced resistance to the sugarbeet root maggot.**

The sugarbeet root maggot (SBRM) is the most destructive insect pest of sugarbeet in the United States. Growers are required to make two applications of insecticide to control the pest in highly infested fields, which increases production costs and potentially exposes non-target organisms, including humans, to toxic insecticides. Consequently, the development of new sugarbeet varieties with genetic resistance to the pest is the most desirable method for pest control. ARS scientists in Fargo, ND, released a new sugarbeet breeding line, ‘F1043’, which has resistance to the sugarbeet maggot that is derived from a unique sugarbeet source not present in other breeding lines resistant to the sugarbeet maggot. Breeding line ‘F1043’ is being used to develop commercial varieties of sugarbeet resistant to the sugarbeet maggot that have the potential to increase profitability and promote more environmentally sustainable production of sugarbeets in the United States.

**Movement of genetic information captured in grapevine.**

Grafting has been widely practiced for centuries for the propagation and production of many vegetable and fruit crops, including grapes. However, the underlying mechanism of how two grafted partners communicate to produce a successful graft are largely unknown. ARS researchers in Geneva, NY, identified 3,000 genes whose genetic code is transported across graft junctions via messenger RNAs (mRNA) in the field. While many biological processes and mechanisms involved in such mRNA movement are yet to be elucidated, one obvious benefit from such exchange of mRNAs between two genetically distinct graft partners would be increased diversity of the genetic information accessible to both shoots and roots as a consequence of grafting. This, in turn, can make the whole plant more productive and adaptive to disease and climate variation; thus, these findings have important practical applications for grape breeding.

**Maize landraces carry tremendous variation necessary for future adaptation to changing environments.**

Maize landraces (farmer varieties) are very diverse and have adapted to many different environments. Identifying the genetic control of this variation, however, has been a slow and tedious process. With new genomic tools and experimental designs, ARS researchers in Ithaca, NY, collaborated with the International Maize and Wheat Improvement Center (CIMMYT) to identify and catalog the genes controlling the large-scale adaptation patterns of maize across the Americas, including those for growing at different latitudes. This efficient approach to tap landrace genetic diversity can be applied to numerous other traits and species, and could be a model experimental design for rapidly accessing the natural diversity of other crops.

**New high-yielding, “low phytic acid” barley cultivar ‘Harriman’ released.**

The problem with grain and legume-based feeds used in non-ruminant animals (poultry, swine, and fish) is that nearly 75 percent of the total phosphorus is in a chemical form called phytic acid, which non-ruminants cannot efficiently digest. As a result, these livestock excrete most of the phosphorus consumed, resulting in high waste phosphorus that contributes to water pollution. Also, excretion of phytic acid phosphorus contributes to poor mineral (iron, zinc, magnesium, and calcium) levels that results in reduced overall animal health and productivity. ARS geneticists and breeders in Aberdeen, ID, have developed a low-phytic acid barley cultivar called ‘Harriman’, which reduces phosphorus waste by 50 percent and has excellent yields. When used as grain component of a feed, ‘Harriman’ barley could result in healthy and more productive animals and reduced the environmental impact of livestock production.

**Markers identified for use in selecting for barley stripe rust resistance.**

Barley stripe rust can cause severe losses in yield and quality of barley, but it does not reliably occur in the breeding nurseries used for selection of new lines. Therefore, breeding progress can be quicker and more efficient if molecular selection can be made regardless of whether the disease occurs in any particular year. ARS researchers in Aberdeen, ID, and Pullman, WA, in collaboration with scientists at the University of California, Davis, and Oregon State University, made crosses with a resistant landrace held in the National Small Grains Collection, mapped four genetic loci associated with resistance, and identified molecular markers that can be used for selection in the absence of disease. This information has been made available breeders in a peer-reviewed journal for use in developing superior, stripe rust-resistant varieties.

**Sugarbeet disease resistance genes identified and characterized.**

The sugarbeet industry in the United States is valued at more than \$2 billion annually. Sugarbeet producers suffer millions of dollars of losses annually to a range of diseases and pests, among which the sugarbeet maggot is especially destructive. ARS scientists in Beltsville, MD, discovered and characterized several disease and pest resistant genes in sugarbeet, and also identified genes in the sugarbeet maggot that are responsible for disease development. The DNA sequences of the sugarbeet genes are used by plant breeders and pathologists to identify new sources of disease resistance in sugarbeets and to devise improved strategies for the development of improved sugarbeet varieties that will benefit farmers by increasing sugar yields for human consumption.

**Identification of *Osmanthus* varieties with tolerance to cold.**

*Osmanthus* species are flowering, evergreen shrubs or small trees popular throughout the southern half of the United States. Little is known about the relative cold tolerance of different *Osmanthus* species, which leaves nursery growers with limited information for choosing *Osmanthus* to grow in their areas and results in considerable losses throughout the United States due to cold stress. ARS scientists in McMinnville, TN, evaluated 16 *Osmanthus* varieties in the field for cold tolerance and identified both highly tolerant and highly susceptible varieties. This information provides nursery growers with guidance to assist them in making data-driven decisions on what varieties are suitable for specific growing regions. The cold-tolerant *Osmanthus* varieties are also being used as parents to develop new varieties that are extremely tolerant of cold.

**“Proxy Selection,” a new approach for altering gene expression in maize.**

Altering expression of genes allows development of crops with improved agronomic performance and reduced environmental impact. Several approaches using biotechnology to alter gene expression have been developed; however, some of these methods rely only on non-native (transgenic) genes. ARS researchers in Ames, IA, have developed an approach called Proxy Selection in which traditional breeding methods are used to select for altered expression of a non-native gene. As a consequence of this selection, the expression of a native gene similar to the transgene gene is altered in a predictable way as well. The changes to native gene expression are maintained in the absence of the non-native gene. Thus, researchers have demonstrated a new method to produce non-transgenic plants with specific alterations in gene expression to investigate gene expression and help understand how genes function to produce valuable traits. This method uses a combination of biotechnology and traditional breeding and may have utility in developing improved non-transgenic crops.

**Unraveling the genetic control of nonhost resistance to wheat stem rust.**

Global wheat production is threatened by new forms of wheat stem rust that defeat many existing stem rust resistance genes. One promising strategy for protecting wheat from stem rust involves a poorly understood type of resistance called nonhost resistance. Using the model grass, *Brachypodium distachyon*, a wild relative of wheat that is a nonhost for wheat stem rust, the genetic control of nonhost resistance was determined to involve genes located at seven chromosome locations. This finding provides the first step toward isolating nonhost resistance genes in *Brachypodium* for use in constructing a new and durable layer of resistance to stem rust in wheat, and in turn increasing food security by protecting global wheat production.

**Identification of a novel gene for resistance to tan spot in wheat.**

Tan spot is a devastating fungal disease of wheat in many wheat-growing regions around the world. Previous research has uncovered several genes in wheat that govern low-levels of tan spot resistance, or resistance to only specific strains of the fungus. ARS researchers in Fargo, North Dakota, identified a new tan spot resistance gene in a wild relative of wheat that provides high-levels of resistance to all known strains of the tan spot fungus. The deployment of this gene into commercial wheat varieties should greatly reduce the economic losses attributed to this disease.

**Resistance to aphids genetically mapped in black raspberry.**

Most of the U.S. production of black raspberry (annual farmgate value of \$16.8 million) is centered in the Pacific Northwest. The current standard commercial black raspberry cultivar is highly susceptible to infestation by the North American large raspberry aphid, which is a vector for the raspberry mosaic virus complex that causes rapid declines in plant health, necessitating re-plant of black raspberry fields after only three to four growing seasons. ARS researchers in Corvallis, OR, have genetically mapped a region of the black raspberry genome associated with host-plant resistance to aphids and elucidated the trait's genetic control. This information should enable breeders to more effectively identify and select aphid-resistant black raspberry varieties.

**Sorghums with cold tolerance are now available through GRIN.**

The United States is the leading sorghum producer in the world, but early season planting and stand establishment is hampered by cool soil and ambient temperature in the U.S. sorghum belt from late

March to early April. Planting at early season is needed to accommodate climatic changes, avail of spring moisture, and aid in realizing higher yield using longer growing season cultivars. ARS researchers in Lubbock, TX, developed, released, and characterized two recombinant inbred populations that have an increased ability to germinate in cooler soil and ambient temperatures (55-58° F). The populations offer wide diversity for improvement of cold tolerance, seed quality, and desirable agronomic qualities, and have been distributed to university breeding programs for evaluation and use as a parental resource for breeding for early season cold tolerance.

**Corn gene that reduces both insect and corn ear mold growth discovered.**

Corn ear molds can produce toxins harmful to people and animals, causing hundreds of millions of dollars in losses in the United States alone. Plant resistance is an economical means to reduce corn ear damage caused by ear rots, but there continues to be a need to determine what genes are involved in producing resistance. ARS scientists in Peoria, IL, evaluated gene coding for a small protein from a corn inbred variety resistant to an ear rot fungus line. When introduced into maize cells, cell clumps that had the gene were not colonized as heavily by a representative fungus compared to cell clumps that did not contain the gene. Insects that fed on the cell clumps containing the gene gained less weight than those that fed on cell clumps not containing the gene. The research appears to be the first discovery of activity of this gene type against insects. This knowledge can be used to guide breeding for ear rot resistance in crop plants that could enhance yield, quality, and safety.

**Spectral reflectance used as a selection tool for drought tolerance by breeders.**

The use of spectral reflectance indices can assist breeders in selecting for drought tolerance in wheat. While selection for productivity in dry environments is a goal of many breeding programs, genetic gain from selection in dry locations is low because of environmental variability and low yields. ARS researchers in Pullman, WA, with colleagues at Washington State University, identified hyperspectral indices that can provide additional information about plant response to drought and whether these indices could serve as indirect selection tools for drought tolerance. The positive associations detected between regression models using hyperspectral data and grain yield could potentially overcome phenotyping bottlenecks and the characterization of larger germplasm collections to identify new sources of resistance to drought.

**Sorghum protein that activates lignin synthesis discovered.**

Lignin is the major structural component of plant cell walls whose presence and composition influences the usability of plant biomass for the production of biofuels and other natural products. ARS scientists in Lincoln, NE, discovered a protein, SbMyb60, that activates synthesis of lignin in sorghum. Experiments showed that increasing the amount of SbMyb60 activated nine genes that increased lignin levels in sorghum biomass. SbMyb60 is the first activator of lignin synthesis to be identified in grasses. SbMyb60 represents a tool to modify plant cell wall composition and has the potential to improve biomass for renewable uses in sorghum and other bioenergy grasses.

**Development of molecular markers for the stem rust resistance gene Sr47.**

The wheat gene Sr47, which was previously transferred from goatgrass into durum wheat, is highly effective in conferring resistance to all strains of the fungal pathogen that cause the disease stem rust. ARS researchers in Fargo, ND, and their collaborators at North Dakota State University developed four new molecular markers that are tightly associated with Sr47. These new markers have the potential to greatly facilitate the transfer and deployment of Sr47 in durum and bread wheat breeding programs, which would help in the development of stem rust resistant varieties.

**GRIN-Global information system implemented.**

Researchers and breeders require access to comprehensive descriptions of plant germplasm's traits to accelerate progress in crop genetic improvement. ARS software developers and plant germplasm curators in Beltsville, MD, and Ames, IA, completed the first major update in 20 years for the Germplasm Resources Information Network (GRIN), the global standard for managing and delivering information associated with plant germplasm. The new "GRIN-Global" was implemented in 2015 in the U.S. National Plant Germplasm System and adopted by six international genebank systems. During 2016, GRIN-Global provided breeders and researchers with access to key descriptions for plant germplasm via more than 1.5 million individual Web page visits, and facilitated distribution of more than 240,000 plant germplasm samples domestically and internationally. Collectively, distribution of germplasm and associated information constituted a technology package that contributed significantly to strengthening crop breeding and research in the United States and internationally.

**The National Genetic Resources Program (NGRP)** is responsible for acquiring, characterizing, preserving, documenting and distributing to scientists, germplasm of all life forms important for food and agricultural production. In FY 2016, 233,289 samples were distributed. The table below lists the number of distributions from the NGRP repositories in the Germplasm Resources Information Network (GRIN) to different organizational categories. Samples are typically distributed to: foreign genebank/resources units; international agricultural research centers; U.S. and foreign commercial companies; and U.S. and foreign agencies and universities.

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Site	Samples	Accessions	Requests	Countries
C.M. Rick Tomato Genetics Resource Center	3,498	1,611	181	23
Cotton Collection	1,687	1,687	82	6
Desert Legume Program	180	168	37	10
Maize Genetic Stock Center	6,656	ND	519	32
National Arboretum	417	341	119	3
National Arid Land Plant Genetic Resources Unit	255	203	33	5
National Center for Genetic Resources Preservation	3,036	2,818	61	5
National Small Grains Collection	48,306	32,044	697	40
National Germplasm Repository - Brownwood	0	0	0	0
National Germplasm Repository - Corvallis	4,299	2,549	604	19
National Germplasm Repository - Davis	2,507	1,287	226	14
National Germplasm Repository - Geneva	5,852	1,815	381	10
National Germplasm Repository - Hilo	115	40	7	4
National Germplasm Repository - Mayaguez	534	252	231	6
National Germplasm Repository - Miami	599	374	61	8
National Germplasm Repository - Riverside	775	455	133	14
North Central Regional Plant Introduction Station	34,812	15,950	1,113	59
Northeast Regional Plant Introduction Station	7,285	4,173	227	19
Western Regional Plant Introduction Station	30,461	18,326	1,290	43
Ornamental Plant Germplasm Center	531	398	52	7
Pea Genetic Stock Collection	89	87	5	2
Plant Genetic Resources Conservation Unit - Griffin	41,093	26,294	905	47
Plant Variety Protection Voucher Collection	40	40	1	1
Potato Germplasm Introduction Station	9,185	4,826	222	8
Rice Genetic Stock Center	8,924	4,462	172	7
Soybean Collection	21,798	11,676	491	28
U.S. Nicotiana Germplasm Collection	355	293	55	1
<b>Total</b>	<b>233,289</b>	<b>168,661</b>	<b>7,905</b>	<b>421</b>



## NATIONAL AGRICULTURAL LIBRARY

The National Agricultural Library (NAL) is one of the largest and most accessible agricultural research libraries in the world. NAL provides services directly to the staff of USDA and to the public, primarily via the NAL Web site, [www.nal.usda.gov](http://www.nal.usda.gov). NAL was formed with USDA in 1862 and was named a national library in 1962 by Congress, as “the primary agricultural information resource of the United States.” NAL is the premier library for collecting, managing, and disseminating agricultural knowledge. The Library is the repository of the Nation’s agricultural heritage, the provider of world-class information, and the wellspring for generating new fundamental knowledge and advancing scientific discovery. It is a priceless national resource that, through its services, programs, information products, and Web-based tools and technologies, serves anyone who needs agricultural information. The Library's vision is "advancing access to global information for agriculture."

### PubAg.

During FY 2016, NAL continued technical development of PubAg, as well as building up content of the service. In September 2016, PubAg reached 49,000 full-text scientific articles written by USDA researchers and 1,340,030 citations to peer-reviewed, agriculture-related scientific articles. Each article citation in PubAg includes NAL Thesaurus subject terms, and a link to the article, if available from the internal NAL repository, PubMed Central, and the publisher. The third phase of PubAg is expected to add 6,000 full-text articles resulting from USDA funding and 400,000 highly relevant citations from scholarly agricultural and allied journals. PubAg can be found at <http://PubAg.nal.usda.gov>.

### **i5K Workspace at NAL.**

In FY 2016, NAL implemented new tools, added new data, and performed updates to the i5k Workspace@NAL, a Web resource for arthropod genome access and curation. New tools include Web applications for the HMMER and Clustal search and alignment algorithms. Ten new species (for a total of 52) and 70 new datasets were contributed by the community and added. A new user interface, new gene pages, the SOLR search engine, and a new metadata submission system were implemented. The i5k Workspace's user base grew to more than 450 registered users, and training was held to familiarize them with available data sets and resources. Eleven articles were published in 2016 citing the i5k Workspace. A high-profile genome project published in 2016, the bed bug, relied on the i5k Workspace infrastructure for its manual curation effort ([www.nature.com/articles/ncomms10165](http://www.nature.com/articles/ncomms10165)).

### **Ag Data Commons.**

In FY 2016, NAL continued development of the Ag Data Commons catalog for agricultural research datasets (<https://data.nal.usda.gov>). Development focused on feature enrichment, increasing transparency for submitters, and adding a curation workflow. Currently, more than 230 datasets with 730 resources for ARS and USDA-funded research results have been deposited. Alliances were initiated with several USDA agencies to encourage dataset deposition in Ag Data Commons and to collaborate on technology development.

### **Long-Term Agro-ecosystem Research Data Portal.**

In FY 2016, NAL developed new data portal components including a viewer to compare historical imagery with almost 600 images of the Long-Term Agro-Ecosystem Research (LTAR) locations, and tools to protect data integrity, particularly tracking corrections to data values during the scientist's quality control and quality assurance processes. Portal data grew to over a half million meteorological observations, and 36 cameras taking high-resolution photographs in two spectral bands to record agricultural field conditions.

### **Life Cycle Assessment Commons.**

In FY 2016, NAL added the "openLCA" product system feature to its unit process data for field crop production. A draft memorandum of understanding, "Cooperation on Data, Research, and Information Systems for Life Cycle Assessment Analysis," was submitted to the USDA Office of Chief Scientist for signature. Co-signers to the MOU include the U.S. Environmental Protection Agency, the Department of Energy, and the National Institute for Standards and Technology. Work was completed on the basic infrastructure and prototype data management application for an LCA Collaboration Server. This technology enables LCA modelers using openLCA to collaborate on modeling activities, then commit data to the LCA Commons using Web services.

### **NAL Digital Collections.**

During FY 2016, NAL digital repository grew to 10 collections, including 49,000 peer-reviewed journal articles authored by USDA researchers and more than 30,000 historical documents and reports. In FY 2016, users downloaded 13,447,529 full-text items.

### **NAL Mass Digitization.**

In FY 2016, NAL digitized and created citation information for 20,275 items (1,083,197 pages), bringing the total number of digitized items in the library's collection to 115,500 (approx. 5.4 million pages). NAL continues a large-scale digitization project to digitize agricultural literature and provide public online access. During FY 2016, NAL focused on historic USDA-issued publications, nursery and seed trade catalogs, and topic-specific content to support NAL online exhibits and information products on subjects such as the Animal Welfare Act and the history of USDA's Bureau of Home Economics. In addition, NAL contributed a number of rare and historical titles to the Biodiversity Heritage Library, including *The Gardeners Labyrinth* (1577), *Die Käfer der Steiermark* (1871), and *Systematic fern-list: a classified list of the known ferns of the United States* (1880). Until all publications are available via NAL Web services, public access is available at

<https://archive.org/details/usdanationalagriculturallibrary>.

### **Online Exhibits.**

In FY 2016, NAL unveiled several online digital exhibits, including “Aprons Strings & Kitchens Sinks” that celebrated the centennial of USDA's efforts in home economics, and “How did we can? The

evolution of home canning.” These exhibits and “NAL-GC”, the library’s quarterly review, were featured in USDA’s daily blog.

### **DigiTop.**

In FY 2016, NAL and USDA partners licensed on behalf of USDA users a \$5.3 million portfolio of content consisting of full-text and databases to support research and scientific discovery. The Operations Division of the Food and Nutrition Service joined as a new member of the DigiTop partnership. Significant new additions to the DigiTop include Annual Reviews of Virology, JoVE (Journal of Visualized Experiments) collection, and back journal files from the “Tri-Societies” (ACSESS Digital Library) and European Journal of Agronomy.

### **Automated Indexing.**

In FY 2016, NAL continued improving full-scale production—automated indexing/text analytics software to generate the AGRICOLA Index of agricultural literature. This application combines semantic analysis, machine learning, and human-constructed rules to assign NAL Thesaurus subject terms automatically to journal article citations and data sets. This metadata facilitates effective literature classification, management, search, and retrieval. In FY 2016, NAL used the system to index 430,126 articles, an increase of 97,446 articles over FY 2014 production. NAL created semantic tools that further enhance the artificial intelligence process for geographic and plant disease concepts. In FY 2017, NAL is expected to complete software upgrades and implement new semantic tools that will integrate thesaurus management and extraction rules to produce a semantically richer concept scheme to enhance automated indexing process.

**Global Agriculture Concept Scheme (GACS).**

In FY 2016, NAL, working in collaboration with Centre for Agriculture and Biosciences International (CABI) and Food and Agriculture Organization of the United Nations, integrated three agricultural thesauri to produce GACS, a core agricultural vocabulary of 15,000 concepts in 26 languages. The vocabulary supports Linked Data and is seen as the first step towards the realization of a hub that links to and from other concept schemes beyond the initial three, and in multiple language areas, to achieve interoperability among information systems. GACS can be found at

<http://browser.agrisemantics.org/gacs/en/>.

### 3.9 Outreach Activities: Workshops, Field Days, and Forums



#### Alabama:

##### **National Soil Dynamics Laboratory**

- Through the USDA Foreign Agricultural Service Cochran Fellowship Program: Cochran Program for Albania Agricultural Extension. The members of the group are working to “develop a modern extension system and enhance agricultural sustainability and food security in Albania” by providing extension managers with innovative methods and knowledge.

#### Arizona:

##### **Arid-Land Agricultural Research Center**

- Undergraduate Irrigation Engineering students and faculty members from University of Chapino,

Mexico, visited ALARC. ARS scientists, Eduardo Bautista, Andrew French and Kevin Bronson, discussed ongoing research in the areas of irrigation modeling, irrigation management, and remote sensing in irrigated agriculture, as well as provided a tour of the center.

- An ARS scientist from the Plant Physiology and Genetics Research Unit was invited to speak at a U.S. Department of Energy (DOE) and USDA collaborative research meeting to discuss future research and collaboration in the field of bioenergy feedstocks and bioproducts. The meeting was held in Golden, Colorado.

### **Pest Management and Biocontrol Research Unit**

- The Journal of Visualized Experimentation (JoVE) filmed a demonstration of the insect immunomarking procedure. The video will be accessible to researchers who are interested in conducting area-wide insect dispersal research.
- Trained a student from New Zealand (stationed in Hawaii) on the protein immunomarking procedure, who used the method to track fire dispersal patterns in the Hawaiian Islands.
- A scientist from the Maricopa, AZ, location traveled to Bangladesh as part of an advisory committee for the USAID project Feed the Future South Asia Eggplant Improvement Project. The committee met with government agricultural research institutes and the Ministries of Agriculture and Environment and Forestry, and visited plot trials and farmer fields.

**Pest Management and Biocontrol Plant Physiology and Genetics, Water Management and Conservation**

- The Center Director provided a tour to Blanca Valera, a staff member for Congresswoman Ann Kirkpatrick (Arizona District 1), of the research center in Maricopa, AZ, to discuss current research projects and results in all three research units.
- The Center Director provided a tour to Mark Killian, the Director of the Arizona Department of Agriculture, of the research center in Maricopa, Arizona, discussing current research projects and results in all three research units.
- Approximately 20 members of the National Corn Growers Association, Research and Business Development Team visited the Arid-Land Agricultural Research Center in Maricopa, AZ, to learn more about the development and application of field-based, high-throughput phenotyping and phenomics-based research.
- An event was held at the University of Arizona, Maricopa Agricultural Center located in Maricopa to inaugurate Advanced Research Projects Agency's Energy Transportation Energy Resources from Renewable Agriculture Program. This program is in coordination with a field scanner that was built on University of Arizona property that will measure crop growth and development at a high resolution.
- An ARS scientist delivered lectures about the effects of elevated CO<sub>2</sub> from free-air CO<sub>2</sub> experiments and its interactions with water supply, soil nitrogen, and warming to scientists at the

Potsdam Institute for Climate Impact Research, Potsdam, Germany, and also to scientists at the University of Bonn, Germany.

### **National Clonal Germplasm Repository for Citrus and Dates**

- Two presentations to industry on: (1) phytoplasma diseases of date palms, and (2) nutrition of date palms.

### **Southwest Watershed Research Center**

- A tour of sites on Fort Huachuca, two private ranches in the San Pedro Valley, and the Bureau of Land Management's Empire Ranch that have had brush management treatments in the past. There were 24 participants primarily from Federal, State, and county natural resource agencies.
- Automated Geospatial Watershed Assessment (AGWA) training class to group of 29 State, Federal, Tribal Agencies and Graduate Students from EPA Region 8, as well as a number of Federal Agencies. AGWA is being used by a number of agencies as a tool to assess the chemical, physical, and biological functions of tributary waters that are regulated under Sections 311, 319, 402, and 404 of the Clean Water Act (CWA) and the National Environmental Policy Act (NEPA).

### **Water Conservation and Management Unit**

- Hosted the Bridgestone Tire vice president and managers from Tokyo, Japan, as well as

scientists and managers from Eloy, AZ. An ALARC scientist provided a tour of the molecular guayule lab, greenhouse, and high-throughput genotyping and phenotyping facilities.

- Meeting to discuss research needs and provide research results on remote sensing, drone deployment, evapotranspiration, and grass variety selection for U.S. golf courses.
- Presented talks entitled, "What Can Field-based Phenomics Offer Southwest Agriculture" and "Updating Cotton Petiole Nitrate Guidelines for Arizona Cotton" to approximately 20 producers, farm advisors, and researchers at the Southwest Ag Summit in Yuma, Arizona.
- Presented ARS research to the GAO-mandated committee to foster sustainable interagency collaboration on research regarding pharmaceuticals in water. Contributed to planning research to reduce redundancy, save money, and increase impact of programs in stakeholder community.
- In coordination with the USDA Foreign Agricultural Service, Eduardo Bautista, Hydraulic Engineer, traveled to Islamabad, Pakistan, to meet with Pakistani agricultural officials and technical specialists for consultation and 3 days of training on Win SRFR and WinFlume software related to surface irrigation, water-efficient technologies, and practices for agriculture.
- Invited by the United Nations Educational, Scientific and Cultural Organization (UNESCO) Institute for Water Education, Delft, The Netherlands, to teach a 4-day course on surface irrigation. The course included training on the use of the ARS WinSRFR software. The audience consisted of 10 Master degree level students from African countries.

- Delivered technical presentations at a workshop for irrigation efficiency, an extension workshop organized by the University of California, Kearney Agricultural Research and Extension Center. The workshop was attended by about 50 participants, mainly producers and consultants. Talked about evaluation of irrigation systems and about the relationship between efficiency and hydraulic design.

### Arkansas:

#### **Dale Bumpers National Rice Research Center**

- Presented an overview of the research conducted at the center, sensory testing of different cooked rice varieties, and hands-on exposure to extracting DNA from plant tissue as part of the genomics emphasis at the center.
- U.S. and international scientists exchanged overviews of research progress on measuring, managing, and mitigating greenhouse gas emissions in rice fields, field tours and research demonstrations, and planning for future collaborations.
- Hosted the National Association of County Ag Agents for a tour of the Center, including the beef cattle and sheep research and the soil nutrient research.

California:

**Commodity Protection and Quality Research Unit**

- Spencer Walse acted as consultant to the California Tree Nut Coalition with USDA Foreign Agricultural Service and key European Union regulatory officials in Germany and The Netherlands.

**Crop Diseases, Pests and Genetics Research Unit**

- Hosted the California Table Grape Commission and San Joaquin Valley table grape growers to an evaluation of early-season and mid-season ARS table grape selections.

**Exotic and Invasive Weed Research Unit**

- Presented an invited talk at the fall meeting of the Oregon State Weed Board in Corvallis, OR, transferring information on impacts and control of aquatic weeds, with emphasis on ARS research and case studies demonstrating approaches to management of invasive water primroses (*Ludwigia* spp.) that are aggressively spreading in the Willamette River watershed.
- ARS scientists hosted the 60th Annual Weed Day tour at Units' Aquatic Weed Research Facility at Davis, celebrating the 50th anniversary of the ARS facility at the Agricultural Experiment Station, transferring information on identification, impacts, and control of aquatic weeds with emphasis on ARS research and case studies demonstrating approaches to

management of invasive aquatic weeds.

- Co-chaired the Aquatic Weed School. Two unit scientists provided presentations for this 2-day event for registered applicators, supervisors, natural resource managers, and State and Federal employees (9/7-8/2016).
- Organized and directed meeting to inform 15 stakeholder agencies and private stakeholder groups about the progress of the ARS Delta Region Areawide Aquatic Weed Project.
- Information on biological control agents for Cap Ivy, Arundo, or Water Hyacinth that are now permitted for field release was provided to stakeholders.

#### **National Clonal Germplasm Repository for Citrus and Dates**

- Presented information on citrus genetic diversity in Citrus Variety Collection to Cibus, Inc. personnel (group of 8).
- Discussed potential citrus planting on California State University's San Bernardino campus. Offered suggestions and ideas for educational aspects.
- Informational flyer distributed to citrus growers distinguishing Citrus tristeza virus from the devastating Huanglongbing (citrus greening) disease. Characteristics of the diseases and best practice recommendations were clearly publicized.

- Presented information on research activities.
- Presented information on date palm cultivation and ARS activities for general public education.
- Presented progress report to stakeholders.
- Assisted with demonstrating fruit varieties to industry personnel, provided information.
- Presented information on germplasm exchange.
- Demonstrated propagation techniques used for citrus (twice in FY 2016).
- Provided information on citrus genotypes to biotech industry.
- Provided information on citrus germplasm conservation, citrus propagation, and pathogen testing. Demonstrated grafting, inoculations, and therapy of citrus germplasm.

#### **Physiology and Pathology of Tree Fruits Research Unit**

- Presented the conference keynote address entitled “Manipulation of the soil microbiome for enhanced system resistance to pathogen proliferation.” This meeting was attended by growers, industry representatives, regulatory personnel, and scientists.

- Information regarding non-fumigant soil-disinfestation research was shared with nursery industry personnel, fruit growers, production consultants, and researchers.

### **Water Management Research Unit**

- The Water Management Unit, Parlier, CA, co-organized a field day on pomegranate water and nitrogen use at the University of California Kearney Ag Center. Field tours of the pomegranate orchard followed presentations.
- Research scientists provided seminars on “Irrigation and Post-Harvest Research to Overcome Trade Barriers.” Specialty Crops Tour group included more than 40 State and Federal agency representatives interested in agricultural practices, pest management policy, field worker safety, and regulation of water and pesticides.

### **Western Regional Research Unit**

- The Western Regional Research Center (WRRC) hosted 25-30 people from the Technical Advisory Committee of the Biomass Research and Development organization (BRD) [<http://biomassboard.gov/index.html>]. The BRD advises the U.S. Secretary of Agriculture and the Secretary of Energy.
- Scientists at Western Regional Research Center, Bioproducts Research Unit hosted 16 students and three faculty members from the Biotechnology and Chemical Engineering programs at the University of Nevada at Reno. The group was interested in rubber, biofuels, bioplastics, and food

safety.

- LTAR (Long-Term Agro-Ecosystem Research) Network California Partnership Meeting was held at the Albany Western Regional Research Center hosted by Andrew Hammond (Area Director, PWA) and Howard Zhang (Center Director, WRRC Albany). Mark Walbridge (National Program Leader, Water Availability & Watershed Management) and Lisa Fischer (Associate Director of the Research and Education Center System, University of California Agricultural and Natural Resources Division, Davis, California) were instrumental in bringing together nearly 30 participants and key partners to facilitate this partnership.
- Hosted the USDA Hispanic Serving Institutions National Program Future Scientists Program Summer Institute. The intent of the program is to train middle-school teachers from the Fresno Unified School District to become more effective in teaching science to their students to positively impact student progress in science and inspire K-12 students to continue their studies in science.

### Colorado:

#### **Central Great Plains Research Station**

- Hosted the Annual Customer Focus meeting at the Research Station, which is held annually to update stakeholder/customers on current research progress, funding, staffing, and facility issues.
- Hosted the annual Sorghum Field Days. This event is a collaborative ARS/CSU event that emphasizes recent sorghum production research conducted by Colorado State University and

ARS. (09/07/2016)

- Three Russian and one German soil scientist/agronomists and seven Russian, Siberian, and Tajistanian farmers visited the station to learn about no-till dryland crop rotations on August 23, 2016.

### **Water Management Research Unit**

- The Water Management and Systems Research unit hosted a field day for local and regional scientists interested in irrigation water management. The unit also hosted the local Agricultural Water Management Chapter for American Society of Agricultural Engineers (ASAE) the same day, August 4, 2016. Water stress monitoring and irrigation optimization technology was shared with visitors.

### **Georgia:**

### **Plant Genetics Resources Conservation Unit**

- USDA National Genetic Resources Advisory Council provided a tour of the Griffin, GA, genebank and presented “National Plant Genetics Program: Responding to Germplasm Requests for Non-Researchers and Backyard Hobbyists.”

### **National Poultry Research Center**

- Center scientists provided updates to stakeholders on research conducted and provided an

opportunity for Stakeholder Committee members from academia, industry, and regulatory agencies to offer input on future directions for research at NPRC.

- Hosted a Stakeholder Committee meeting at the Russell Research Center in Athens, GA. Center scientists provided updates to stakeholders on research conducted at the Center since the last stakeholder meeting in 2013.

### Hawaii:

#### **Daniel K. Inouye U.S. Pacific Basin Agricultural Research Center**

- Hosted the U.S.-China Biotechnology Working Group and Technical Working Group meetings. The delegation included participants from USDA Animal and Plant Health Inspection Service, USDA Foreign Agricultural Service, U.S. Environmental Protection Agency, U.S. Food and Drug Administration, and the China Ministry of Agriculture. Presented a 1-day papaya field day to share experience in developing and deregulating Hawaii's genetically engineered papaya.
- Participated in the Hawaii Department of Agriculture's Interagency Biosecurity Workshop. Provided information on DKI-PBARC's research in detection, mitigation, and quarantine treatment of invasive insect pests.

#### **Tropical Plant Genetic Resource and Disease Research Unit**

- Presented to growers on "Management of Plant-parasitic Nematodes in Nursery Production."  
Reported on screening ginger cultivars for nematode resistance, *Anthurium* chemical trials, and

media disinfestation with hot water drenching and steam sterilization.

- Hosted the Kaumana Drive Seniors Group at DKI-PBARC. Discussed the Zero-Waste project, Rapid Ohia Death, and the People's Garden.
- Hosted members of the Hawaii Department of Agriculture. Went over sampling and testing protocols used to detect the Rapid Ohia Death fungus.
- Hosted eight students and two chaperones from the Kohala Center's high school agriculture internship program. The goal of the program is to get students excited about food and farming by meeting professionals in the field of agriculture, and by experiencing day-to-day farm life from "seed-to-sale". The students were given a tour of the germplasm repository and the staff shared their paths after high school to get to where they are today.
- Hosted Pablo Benavides Machado, coffee berry borer (CBB) expert from Cenicafe, Colombia, to share his expertise on CBB control with coffee growers in Oahu, Kauai, Maui, Kona, and Ka'u. He also meet with ARS, University of Hawaii, and Hawaii Department of Agriculture scientists to discuss similarities and difference in CBB control in Colombia and Hawaii to build future collaborative research in controlling this pest.
- Hosted the Kohala Center's Adult Beginning Farmer Training Program for a tour of Daniel K. Inouye U.S. Pacific Basin Agricultural Research Center germplasm repository and the Nowelo laboratory facilities. Derrick Kiyabu, the program coordinator, and 15 students attended.

Idaho:

**Aberdeen Barley Breeding Program**

- Co-hosted the food barley breeder collaboration meeting via tele-conference in Idaho. Participants included universities, seed industry, and trade business. Provided guidelines for standard check use in field experimental designs across the breeding programs and approved collaborative field evaluations for elite lines from different breeding programs.

**Horticultural Crops Research Unit**

- Delivered an oral presentation to industry members at Sawtooth Winery in Nampa, Idaho, describing a new water stress index and its potential use as an irrigation decision-support tool.
- Discussed thermal-imagery-based modeling for precision irrigation of wine grapes during a networking forum with industry stakeholders that develop ag-related software and sensor technology for precision-agriculture applications.
- ARS scientist was invited to give an oral presentation to Idaho wine grape industry stakeholders about the new irrigation decision-support tool being developed in the wine grape research program.

### **Northwest Irrigation and Soil Research Laboratory**

- Industry personnel viewed sugar beet cultivars being screened for resistance to curly top, rhizomania, and Rhizoctonia root rot, and were informed of research projects associated with sugarbeet germplasm development, the impact of long-term manure rotation on soil nutrients, and new approaches to curly top control in sugarbeet.
- Introduction to agricultural research including job opportunities and research associated with ARS was presented to the general public.
- David Bjorneberg, David Tarkalson, and April Leytem participated in the Idaho Dairymen's Association Nutrient Management Workshop to help educate dairy producers and industries serving dairy producers (environmental managers, crop consultants, etc.) about better nutrient management on farms.

### **Small Grains and Potato Germplasm Research Unit**

- Hosted 37 seniors from Idaho State University's New Knowledge Adventures program by organizing a short course entitled, "Exploring the world of plant breeding and genetics at the National Small Grains Germplasm Research Facility."
- Discussed an ARS patent-pending method for generating barley protein concentrate for fish feed and channeling the residue components to a corn ethanol plant nearby. A company is interested in conducting a pilot scale test of the technology.

- Met in separate meetings with representatives of two potato processing companies to present information on Aberdeen potato breeding clones/varieties. Information was presented and input received back on several clones/varieties currently being evaluated by those companies.
- Introduced our elite barley lines for uses of malting and food.

### Illinois:

#### **Crop Bioprotection Research Unit**

- Gave a seminar to a microbiology class of nursing students from Order of Saint Francis (OSF) St. Francis Medical Center, Peoria, IL.
- Gave a seminar to an agronomy class of students from Illinois Central College, East Peoria, IL.
- Gave a seminar to an "economic botany" class of students from Illinois State University, Bloomington, IL.
- The presentation covered research performed in 2015, which indicated low lignin lines of sorghum generally did not have increased levels of insect damage or disease compared to the normal lignin line.

Iowa:

**National Laboratory for Agriculture and the Environment**

- Presentation "Cover Crop Management in Iowa" at Polk County Extension Office, Altoona, Iowa. (3/2/16)
- Presentation of "Use of Cover Crops for Nutrient Loss Reduction" at Sukup Hall, Iowa State University, Ames. (3/23/16)
- Presented a Cover Crop Update at Iowa State University, Northeastern Iowa Research Farm, Nashua, Iowa. (6/28/16)
- Presentation of "Cover Crops" at Iowa State University Agricultural Engineering and Agronomy Research Farm, Boone, Iowa. (7/27/16)
- Developed and delivered training workshop on Agricultural Conservation Planning Framework (ACPF) watershed planning software that develops precision conservation planning options for watershed improvement. (3/15-16/16)
- Developed and delivered training workshop on ACPF watershed planning software that develops precision conservation planning options for watershed improvement. (8/23-25/16)
- Provided information on research and monitoring of crop growth, soil water, and water quality in

the South Fork Iowa River watershed, and development of multi-scale information using ground-based observations and satellites.

- Participated in the Iowa Independent Crop Consultants Annual Meeting in Ames, and presented an overview of how various soil and crop management strategies affect potassium availability in soil and uptake by the crop.
- Participated in the annual meeting of the Southern Extension and Research Activities Information Exchange Group on Minimizing Agricultural Phosphorus Runoff Losses for Protection of the Water Resource (SERA-17) (11/19/2015).
- Participated in the annual meeting of the Soil Science Society of America in Minneapolis, Minnesota. Provided an update on current research addressing potassium-use efficiency and crop uptake (11/17/2015).
- Participated in the 8th International Phosphorus Workshop in Rostock, Germany. Presented an overview phosphorus acquisition by riparian plant species (9/8/2016).
- Iowa State University/University of Iowa-sponsored conference on organic agriculture. Invited to present seminar and participate on expert panel about water quality in organic farming, Iowa City, IA. (12/23/15)
- Iowa State University-sponsored conference on soil health. Invited to present seminar entitled “Soil Health and Ecosystem Services in Alternative and Perennial Cropping Systems,” Ames.

(2/2/16)

- The Organic Center's Conference on Environmental Impacts of Organic Agriculture. Invited by The Organic Center to present seminar about research on water quality in organic farming systems, Washington, D.C. (5/23/16)
- National Press Foundation sponsored in-depth training for journalists on the future of food and agriculture in the United States. Invited by The Organic Trade Association to present seminar about research on water quality in organic farming systems. St. Louis, MO. (7/16/16)
- Iowa Organic Association-sponsored field day. Invited presentation about water quality in organic agriculture. Boone, IA. (6/28/16)
- Iowa State University-sponsored conference on soil health. Invited to present seminar entitled Soil Health: Historical Perspectives, Boone, IA. (9/22/16)

### **Soil, Water, and Air Resources Research Unit**

- Presented on field efficacy of humic products to farmers in Fargo, North Dakota (03/10/2016).
- Presented on field efficacy of humic products at National No-Tillage conference in Indianapolis, IN (01/07-08/2016).
- Gave four presentations on field efficacy of humic products and soil biochemistry research at two universities and biannual humic substances conference in Brazil (10/13-23/2015).

- Gave presentation on humic product efficacy to county agronomists of Iowa State University (09/22/2016).

### Kansas:

#### **Hays**

- Wheat Breeders Field Day: 2 scientists attended.
- Trade Mission Field Day: 2 scientists attended.
- Co-organized annual Hard Winter Wheat Breeders' Field Day. Presented lines entered in ARS Regional testing program.

#### **Hutchinson**

- Hutchinson Experiment Station Field Day: 2 scientists attended.

#### **Kansas State University, Hays**

- Attended annual meeting of the USDA Regional Performance Nurseries for Hard Winter Wheat and presented crop data for 2015 harvest.

- Attended sorghum field day at the Kansas State University, Western Kansas Agricultural Research Station.

### **Manhattan**

- Attended the field day at the Sorghum Improvement Conference of North America.
- 20 students visited Dr. Bai's lab to learn high-through put genotyping.
- John Fellers was on a panel discussing genetically modified organisms (GMO) issues for the Kansas State Research and Extension Horticultural Specialist Continuing Ed conference.
- Attended session demonstrating utilization of sorghum, “Bioprocessing and Industrial Value Added Products” Center at Kansas State University.
- Attended Pioneer Hybrid tour of their Manhattan, KS, sorghum breeding site (9/20/2016).

### **Wichita**

- LimaGrain Field Day: 1 scientist attended.

Kentucky:

**Food-Animal Production Systems Research Unit**

- Planned, organized, moderated, and spoke at the 2016 Cell Biology Symposium: Membrane Trafficking and Signal Transduction that was held at the American Society of Animal Science annual meeting in Salt Lake City, UT (7/20/16).
- Gave a seminar entitled "Accomplishments in Fescue Toxicosis Research" to members of the academic, extension, producer, and industry communities on accomplishments FAPRU has made in the last 5 years regarding Fescue Toxicosis (5/26/16).
- Presented to producers and industry representatives at producer society conference. (1/25/2016)
- Conducted a week-long anaerobic microbiology workshop at Langston University. (3/28/16 - 4/1/16)
- Conducted a 2-day anaerobic microbiology workshop for Warren Wilson College students. (11/14-15/2015)
- Presented on research results on feeding soybean hulls to cattle grazing toxic endophyte-infected tall fescue. (1/26/16)
- Presented on how ergot alkaloids adversely affects the physiology and performance of cattle.

(1/27/16)

- Provided an update on research accomplishments of Unit. (1/11/16)
- Presented research results on research done on the effects of biochanin A, produced by red clover, on beef calf performance and well-being. (2/21/16)
- Presented research results on research done on the effects of biochanin A, produced by red clover, on beef calf performance and well-being. (3/22/16)
- Presented on how ergot alkaloids adversely affects the physiology and performance of cattle. (3/22/16)
- Provided a review of fescue toxicosis research. (6/5/16)
- Discussed chemical seed head suppression of toxic endophyte-infected tall fescue. (6/13/16)
- Discussed planting and management of novel endophyte tall fescues. (6/16/16)
- Discussed the research conducted at the farm.
- Presented the research on chemical seed head suppression of toxic endophyte-infected tall fescue. (9/9/16)

- Discussed planting and management of novel endophyte tall fescues. (6/16/16)
- Discussed mitigation of fescue toxicosis. (9/22/16)
- Presented research on mitigation of fescue toxicosis. (10/19/16)
- Presented research results on research done on the effects of biochanin A, produced by red clover, on beef calf performance and well-being. (11/8/16)
- Provided an update on research accomplishments of FAPRU. (12/1/16)

### Louisiana:

#### **Honey Bee Breeding, Genetics and Physiology Research Unit**

- Presented a workshop consisting of lecture and discussion sessions and some hands-on experience with the Unit's bee colonies.
- Consulted about technical aspects of testing, selecting, and breeding honey bees for resistance to Varroa mites, and acquired semen from Varroa-resistant honey bees for use in a research and breeding program in France.
- Hosted a "Beginning Beekeeping for Veterans" workshop in partnership with the Louisiana Armed Forces Foundation and the NRCS StrikeForce Initiative. The goal of the workshop was

to provide veterans and their families with hands-on knowledge regarding the potential use of beekeeping and agriculture as a tool to help veterans reduce stress and aid in recuperation, in addition to the potential of turning their beekeeping efforts into a way to generate some extra income through hive-based products.

- Discussed technical aspects of a collaborative breeding project aimed at improving commercial adoption of mite-resistant honey bees.

### **Southern Regional Research Center**

- Administrator Chavonda Jacobs-Young, SEA Area Director Deborah Brennan, and many present and past SRRC employees, collaborators, stakeholders, senior ARS leadership attended a ceremony commemorating the 75th anniversary of the ARS Southern Regional Research Center.

### **Maryland:**

#### **Beltsville Agricultural Research Center**

- Conducted a field day September 10 that provided an opportunity for ARS scientists in Beltsville to display their research and its vital role to agriculture and the lives of the public. Other exhibits included: Friends of Agricultural Research - Beltsville (FAR-B); the Lions Club; Safety, Occupational Health and Environmental Staff (SOHES); and the National Agricultural Library (NAL).

**Massachusetts:**

**Jean Mayer Human Nutrition Research Center on Aging at Tufts University**

- HNRCA research-based nutrition guidance was translated into Mandarin Chinese by an ARS scientist. He also presented the information, answered questions, and distributed guidance at 3 senior centers with Chinese language-speaking attendees (approximately 250 copies were distributed).

**Metabolic Research Unit at Tufts University**

- In mid-June, the Metabolic Research Unit hosted 50 volunteers who have participated in research studies at the HNRCA for a morning of appreciation.

**Michigan:**

**Avian Disease and Oncology Laboratory**

- Conducted wetlab on poultry necropsy for wildlife course at Michigan State University (12/2/15).
- Gave lecture and lab on avian tumor virus diagnosis for pathology residents at Michigan State University's Diagnostic Center for Population and Animal Health. (5/12/16)

### **Sugarbeet and Bean Research Unit**

- Gave two presentations: "A new imaging technique for enhanced detection of defects on apples." and "Development of a self-propelled apple harvest and automatic in-field sorting machine" to apple growers and packinghouse operators.
- Gave a poster on the progress on apple harvesting and sorting research.
- Gave a tour to the engineering lab and showed our apple harvest and sorting project funded in part by Michigan Apple Committee.
- Demonstrated and tested the new apple harvest and sorting machine prototype to a select group of about 20 people from the Michigan apple industry, extension specialists, and researchers.
- Gave a short presentation on ARS research in East Lansing, MI, and showed response of ARS breeding materials in field trials.
- Sugarbeet scientists presented talks on current pathology and breeding research.
- Presented talk, followed by a discussion session about plant pathology and agricultural research in Texas.
- Created sugarbeet nurseries in collaboration with Beet Sugar Development Foundation and made

them available to industry leaders for informational purposes.

- Conducted a 1-day seminar/lab tour for five visiting scholars from Pakistan. Topics covered included description and testing of rating scales; presented developmental visual aids for raters; and new research developments and tools.
- Gave presentation "Formulation and Quality Assessment of Pilot Scale Prepared Products Using Dry Bean Ingredients."
- Gave presentation, "Beans as Ingredients in 'Better for You' Foods."
- Presided as Chair of the Scientific Committee; presented research and site visit in France.
- Consulted and provided training on beet pathogens and recognizing various beet diseases.
- Mycology consultant on assessing biosafety and agricultural safety of potential bio-fermentation materials.
- Working with Michigan State University and industry on educational and outreach priorities for sugarbeet in Michigan.

Minnesota:

**Fargo**

- Sunflower and Plant Biology Unit scientist and university collaborators presented oral and poster presentation on current research to stakeholders from the sunflower, canola, bean, pea, lentil, and soybean community.
- Sunflower and Plant Biology Unit scientist presented update on sunflower screening trials seeking to identify germplasm with resistance to *Sclerotinia* diseases.

**Soil Management Research Unit**

- Presented research concerning dual cropping with winter oilseeds in corn-soybean systems.  
(11/15)
- Demonstrated research on winter annual cover crops for sustainable ag production. (7/16)
- Presented "Cover crops - protecting the thin layer that stands between us and starvation."  
(8/30/2016)
- Participated in a roundtable discussion on lab research on soil and water conservation. (4/7/2016)
- Presented Lab research activities on new crops and natural resources conservation to college

students. (7/12/16)

### Mississippi:

#### **Cotton Ginning Research Unit**

- Cotton Ginning Research Unit and the Office of Technology Transfer hosted the Stoneville Ginners School sponsored by the National Cotton Ginners Association.
- Cotton Ginning Research Unit co-hosted a meeting with Delta Council for the Southern Cotton Ginners Association to speak to producers and ginners on the latest research in cotton ginning.

#### **Watershed Physical Processes Research Unit**

- Hosted the 2016 S-1048 Regional Meeting: Assessment of the Carbon Sequestration Potential of Common Agricultural Systems on Benchmark Soils across the Southern Region Climate Gradient.

### Montana:

#### **Fort Keogh Livestock and Range Research Laboratory**

- Fort Keogh scientists presented research results and discussed research results during several

location tours.

- Dialogue, discussion with ranchers from Sidney Montana concerning management questions and application of Fort Keogh research.
- Pre-bull sale educational seminar and discussion of bull fertility research conducted at Fort Keogh.
- Buyers come to Fort Keogh to purchase bulls by auction.
- Dialogue, discussion with ranchers from Biddle, Montana, concerning management questions and application of Fort Keogh research.
- Students enrolled in rangeland management, beef cattle production, and nutrition courses take a field trip to the laboratory to learn about research being conducted by the laboratory's range ecology and beef cattle groups.
- Students enrolled in Wildlife Management and ecology courses take a field trip to the laboratory to learn about research being conducted by the laboratory's range ecology and beef cattle groups.
- Half-day experience for summer science camp student's work on science and rangeland projects.
- Two half-day tours and classroom style presentations concerning history and natural resources and beef cattle research.

- Dialogue and discussion with land owners and agency personnel concerning management questions and application of Fort Keogh research.

### **Northern Plains Agricultural Research Laboratory**

- Conducted business meeting with stakeholder group the Monday before Thanksgiving at the Sidney, MT, location.
- Hosted seven different presentations from January to early April 2016, including: (1) improved techniques for restoring damaged grasslands; (2) talk and demonstration of 3-D printing; (3) weed resistance in sugarbeets; (4/5) two talks on techniques for improving soil health; (6) evaluating side channel impacts on fish in the Yellowstone River; and (7) identifying invasion mechanisms of invasive annual grasses and finding practical, process-based management solutions.
- Erin Espeland helped coordinate the conference and also spoke on "Cover Crops and Reclamation." Other ARS personnel contributed posters to the event.
- Circle (MT) Farm Show, Jan. 30; National Hard Red Spring Wheat Show, Williston, (ND), Feb. 3-4; Glendive (MT) Agri-Trade Exposition, Feb. 12-13; MonDak Ag Days in Sidney, Mar. 3-4, and the KATQ NE MT Ag Exposition in Plentywood (MT) March 18-19.
- Annual event features tours of dryland projects underway at the research farm, as well as outside speakers on agricultural topics of interest.

- Annual event features tours of the MSU and ARS research farms near Sidney.
- Staff provided a tour focused on learning about agricultural insects (both pest and beneficial) and related biological control research for elementary grade club members as part of their summer education program.
- NPARL Agronomist Bart Stevens provided information on a 6-year cropping system study by ARS with sugarbeet, barley, corn, and soybean in 2- or 3-year rotations.
- Insect Ecologist Tatyana Rand demonstrated insect sweeping and identification techniques at the Montana State University Swank Tour held 7/19/2016 at the Paul Swank farm.
- Featured exhibits for both adults and youth throughout the 4 days of the fair Aug. 3-6.
- NPARL scientists and staff helped organize and spoke at the Russian Olive Restoration Workshop held Sept. 12-13 at the Fort Keogh ARS facility in Miles City. University of Montana, U.S. Forest Service, and NRCS representatives also participated.

### Nebraska:

#### **Sidney, Alliance Hemingford, Chappell**

- Attended University of Nebraska-sponsored field days to present new ARS developed potential

wheat cultivars to Nebraska wheat farmers and seedsmen.

### **Wheat, Sorghum, and Forage Research Unit**

- Hosted a field tour of our location's bioenergy and forage research to 20 members at the NC1178 Annual Meeting, University of Nebraska, Mead, NE, June 28, 2016.
- Hosted a site visit and field tour of bioenergy research to a visiting scientist from Texas A&M University, University of Nebraska, Mead, NE, June 29, 2016.

### *Nevada:*

### **Great Basin Rangelands Research Unit**

- At the X International Rangeland Congress in Saskatoon, Saskatchewan, Canada, ARS scientists from Reno, Nevada, Tucson, AZ, and Boise, ID, held a half-day workshop to provide background on dominant rangeland hydrologic and erosion processes, equations implemented in the Rangeland Hydrology and Erosion Model, and how to access and interpret model predictions.
- At the Nevada Section, Society for Range Management annual summer field tour, the Unit led a discussion on the importance of range improvement practices to improve habitat for wildlife and grazing resources and enhance sustainable agricultural practices. Control methodologies of cutting pinon juniper woodlands to release shrubs, grasses, and forbs for wildlife and grazing

resources, as well as hydrological benefits, were presented.

- Personnel from the Unit, in conjunction with the National Agricultural Library (NAL), attended the Global Open Data for Agriculture and Nutrition (GODAN) meeting in New York, New York. Unit and NAL staff demonstrated the ARS relational rainfall simulation database (Agricultural, Runoff, Erosion, and Salinity – ARES) in addition to the Rangeland Hydrology and Erosion Model (RHEM tool).

### **Water Management and Conservation Unit**

- Provided expertise in designing a system to reuse treated municipal wastewater for irrigation of fresh produce in greenhouses. Produce grown locally will not impact water resources and can reduce energy consumption.

### **New Mexico:**

#### **Southwestern Cotton Ginning Research Laboratory**

- The Gin tour to 30 Mexican agricultural exchange students from New Mexico State University (NMSU).
- Gin tour to six Chinese agronomists from the Department of Agricultural Technology in Henan, China.

- Gin tour to chemistry class from New Mexico State University (28 students).
- Cotton processing presentation and ginning demonstrations to nearly 500 students from Grant and Catron Counties at the Ranch Days held at the McKeen Ranch near Glenwood, NM.
- Cotton processing presentation and ginning demonstrations at the Kids, Kows, and More Program for 4th and 5th graders held at the Farm and Ranch Heritage Museum in Las Cruces, NM.
- Cotton processing presentation and ginning demonstrations at the New Mexico State Fair in Albuquerque, NM.
- Gin tour to New Mexico State University Agriculture Education 100 Class with overview of career opportunities of research and jobs in USDA (20 students).

*New York:*

**ARS Robert W. Holley Center for Agriculture and Health**

- Empire Farm Days is where farmers, agribusinesses, and industry leaders come together for buying and selling and brainstorming the next great idea (August 9-11). ARS scientists displayed and explained research performed at the Robert W. Holley Center.
- The Northeast's premier indoor farm show was held February 25-27, 2016, at the New York

State Fairgrounds in Syracuse. The Center had a booth where scientists answered questions from the public and displayed their research.

## **Victor**

- Keynote presentation to the NY Cherry marketing and Research Board on progress of stoneless plums.

## **North Dakota:**

### **American Society for Nutrition**

- Answered questions from students regarding career development.

## **Fargo**

- Updated the Executive Directors of the Northern Canola Growers Association on current research related to winter hardiness of winter canola and *Sclerotinia* projects sponsored by the association.
- Co-organized the Sunflower Research Forum; Sunflower and Plant Biology Unit scientists and staff presented oral and poster presentations on current research.

- Sunflower and Plant Biology Unit scientists and staff gave the National Sunflower Association Board of Directors laboratory and greenhouse tours in conjunction with various sunflower research projects.
- Hosted 48 high school science teachers attending the North Dakota Geographic Alliance Summer Institute for a lab tour and research review.

#### **Hoverson Farms, Inkster**

- Sugarbeet and Potato Unit scientists attended and gave presentations.

#### **Institute of Food Technology Conference**

- Presentation on Carbohydrates in Weight Management.

#### **Neuropsychiatric Research Institute**

- Seminar entitled: “Seminar for obesity, inflammation and microbiome.”

#### **North Dakota Beed Commission Conference**

- Presentation to North Dakota Beef Commission Board Meeting.

### **Northern Great Plains Research Laboratory**

- Partnered with North Dakota State University, Bismarck State College, NRCS, and the Area 4 SCD Research Farm to develop a major day-long program to assist family farmers manage through financially difficult times.
- Annual USDA open house showcased agricultural and environmental research for more than 700 people from local farms and ranches and the community.
- Hosted dozens of family ranchers on a winter grazing tour sponsored by Burleigh County Soil Conservation Service.
- Hosted 48 high school science teachers attending the North Dakota Geographic Alliance Summer Institute for a lab tour and research review.

### **The Red River Agricultural Research Center**

- Sugarbeet and Potato Unit scientists attended and gave presentations (USDA Fargo Sugarbeet Genetics Overview and USDA Fargo Sugarbeet Pathology Overview).

### **University of Minnesota**

- Presentation for University of Minnesota Nutrition Students and Faculty.

## University of North Dakota

- Seminar for Epigenetics students/faculty entitled, “Intergenerational Transmission of Obesity: Role of Beige Adipocytes.”
- Presentation for the Nutrition students in their Nutrition 101 class.
- Presentation for University of North Dakota Pharmacology and Physiology Department.

## Ohio:

### Application Technology, Toledo

- Made presentation entitled, “Benefits of silicon in greenhouse production,” at the Floriculture Research Alliance annual research meeting, with approximately 60 attendees, including greenhouse owners and growers, researchers, and allied industry trade members.
- Made presentation entitled, “Control of horseweed (*Conyza canadensis*) in field nursery crops,” at the Northeast Weed Society meeting with about 50 attendees, including weed scientists and allied industry trade members that deal with weed control issues.
- Provided overview of the research program of the ARS Greenhouse Production Research Group in Toledo, Ohio, through oral presentations by researchers, handouts, and Q & A interaction.

- Made presentation entitled, “Virtual Grower – A software tool to manage greenhouse energy costs,” to the New Jersey Vegetable Growers Association Conference with about 50 attendees including scientists, extension agents, and growers.
- Made presentation entitled, “Controlling difficult weeds,” at Cultivate’ 16. The seminar had about 100 attendees including greenhouse and nursery growers, weed scientists, and other in the green industry.
- Published article: *New technology development in water treatment*, in Greenhouse Grower Technology, a national trade magazine read by Greenhouse and nursery growers, researchers, and allied industry trade members.
- Virtual Grower, a decision-support software program, is available for download from the Web site, [www.virtualgrower.net](http://www.virtualgrower.net). This program is widely used by growers, students, and researchers to build a virtual greenhouse, estimate energy costs, compare the relative efficiencies of different structures, and predict crop growth timing.
- PhotoSim, a decision-support software, is available for download from the ARS Web site, [www.ars.usda.gov/midwest-area/wooster-oh/application-technology-research/docs/photosim-leaf-photosynthesis-model-for-floriculture-crops](http://www.ars.usda.gov/midwest-area/wooster-oh/application-technology-research/docs/photosim-leaf-photosynthesis-model-for-floriculture-crops). It is used by students, researchers, and growers to predict the impact of lighting, shading, heating, cooling, and CO<sub>2</sub> supplementation decisions on crop growth.

### **Corn, Soybean, and Wheat Quality Research Unit**

- Gave invited talk entitled, “Assessing the impact of Ohio wheat viruses (update),” to a growers board meeting, update on funded project. Shared data on viruses and studies on their impact in Ohio wheat, conveying and discussing important next steps to assess their impact on production; ongoing project with wheat growers, November 2015.
- Provided guest lecture on plant viruses for General Plant Pathology course, Wooster, Ohio (video linked to Columbus and Mansfield), attended by approximately 100 Ohio State University Plant Pathology and biology graduate and undergraduate students, October 2015.
- Invited talk entitled, “Virus populations associated with Maize lethal necrosis (MLN) in East Africa,” at North Carolina State University Emerging Plant Disease and Global Food Security symposium. Meeting attended by plant pathologists, public policy leaders, agricultural production and technology industry members, and students.
- Transfer: Visited maize fields across Tanzania to train personnel in field surveying for Maize lethal necrosis (MLN) and other virus disease, Dar es Salaam, Morogoro, Mbeya, Iringa, Kilimanjaro, Manyara, and Moshi, Tanzania.
- Shared data on “Corn eating viruses and their vectors” during a reciprocal Borlaug scholar visit and invited talks at Ho Chi Minh City Open University, Nam Long University, and Cuu Long Rice Research Institute in Vietnam.

- Poster entitled, “Emergence and Spread of Maize Lethal Necrosis (MLN) in East Africa,” displayed at the Emerging Plant Disease and Global Food Security Symposium at North Carolina State University. Meeting attended by researchers working on diverse aspects of emerging crop diseases and their control.
- Made invited seminar presentation entitled, “The Spread of Maize Lethal Necrosis in East Africa,” for the Innovative Agricultural Research Initiative (iAGRI) Program, Sokoine University, Morogoro, Tanzania. Meeting was attended by iAGRI and Sokoine University students, faculty, and administrators.
- Gave talk entitled, “Phenotyping for resistance to viruses in maize,” at the Promising Phenotyping Efforts for Understanding Genetic and Molecular Basis of Plant Disease Resistance Symposium, attended by public and private researchers and students.
- Gave lecture and lab for Ohio State University, Plant Pathology, PP5685 Plant Disease Diagnostics, attended by Graduate students in Plant Pathology.
- Presented several talks entitled, “Volatile organic compound profile of sound wheat grain,” “Improvement of volume and contour of steamed bread by reduction of starch amylose content with incorporation of waxy wheat flour,” “Wheat maturity time giving the maximum grain yield and highest falling number (indicative of pre-harvest sprouting),” “Effects of nitrogen fertilizer rate on milling and baking quality traits of eastern soft wheat,” and “Improvement of volume and contour of cakes baked from non-chlorinated flour by starch addition, formula modification, and pre-heat treatments of flour,” at the Soft Wheat Quality Laboratory Research Review Annual

Conference.

- Made oral presentation entitled, “Uniqueness and extended use potentials of eastern soft wheat,” given to the current and potential eastern soft wheat buyers at the Latin American and Caribbean Wheat Buyers Conferences hosted by the U.S. Wheat Associates.
- Presented, “Milling and baking quality improvement efforts for eastern soft wheat,” at the Rural Development Administration (RDA)-Korea. Meeting attended by RDA-Korea scientists researching wheat breeding and food technology.
- Made presentation entitled, “End-use quality improvement of eastern soft wheat for better marketability,” at the Maryland Grain Producers Utilization Board Research Review Meeting. Meeting attended by grain growers, wheat breeders, and traders.
- Two Soft Wheat Quality Laboratory scientists gave talks on the effort to improve the milling and baking quality of eastern soft wheat at the Ohio State University 2016 Wheat Field Day.
- Made presentation entitled, “Plant virus diagnostics,” at the International Plant Diagnostics Short course. Lectured on plant virus symptoms and diagnosis to International plant pathologists and pathologists in training at Ohio State University, September 2015.

### **Soil Drainage Research Unit**

- Provided Webinar entitled, “Edge-of-field research: what are we learning,” to the 76 members

and stakeholders of the Michigan Farm Bureau (10/6/2015).

- Gave presentation entitled, “Practices to address edge-of-field P losses in Lake Erie Basin,” to the Western Lake Erie Basin Working Group (10/15/2015).
- Made presentation, “Agricultural Phosphorus Losses: What is edge-of-field data telling us?” and gave a tour of edge of field sites to Ohio Congressmen and staff (10/16/2015).
- Made presentation, “Managing agricultural phosphorus for improved water quality: challenges and opportunities,” to the Olentangy Watershed Forum, Powell, Ohio (10/22/2015).
- Made informal presentation, “What are we learning from edge-of-field data?” to 40 EPA, Farm Bureau, and Lake Erie stakeholders (10/26/2015).
- Made two invited presentations, “Monitoring surface runoff and tile drainage using automated and passive sampling,” and “Edge-of-Field Water Quality Monitoring,” to 225 Water Quality, instrumentation, policymakers, and producers (12/2-3/2015).
- Presented, “Assessing edge-of-field water quality: Practices to decrease phosphorus loss,” to Ohio Federation of Soil and Water Conservation Districts Area 2 Winter Meeting, Wadsworth, Ohio (12/7/2015).
- Made presentation entitled, “Measuring Nutrient Loss in Edge-of-Field Surface and Tile Drainage,” at the National No-Till Conference in Indianapolis, Indiana. This conference was

attended by 900 to 1,000 national and international no-till producers (1/7/2016).

- Made presentation entitled, “Water Quality and Phosphorus Management,” at the 2016 Corn/Soybean Day in Archbold, OH (1/22/2016).
- Made presentation entitled, “Edge-of-Field Research: Not all Fields are the Same,” at the 2016 Great Lakes Crop Summit in Mount Pleasant, MI (1/27/2016).
- Made presentation entitled, “Assessing edge-of-field water quality: Structural and management practices to decrease phosphorus loss,” to the Ohio Land Improvement Contractors Association. Dublin, OH (1/6/2016).
- Made presentation entitled, “Edge-of-field water quality in Ohio,” to the Ohio Farmers Union, Columbus, OH (1/29/2016).
- Made presentation entitled, “Current Edge-of-Field Research Findings,” and led a discussion at Frazier Heiby (public relations group for Ohio Corn and Wheat Growers) in Columbus, OH (2/9/2016).
- Made presentation entitled, “Water Quality Monitoring,” to the 2016 Ohio Pork Congress in Columbus, OH (2/10/2016)
- Made presentation entitled, “Edge-of-Field Water Quality Research: Not all Fields are the Same,” at the Solutions from the Farm meeting.

- Gave an illustrated lecture on Drainage Water Management in Ohio to the Ohio U.S. Natural Resources Conservation Service State Technical Committee at London, OH (3/24/2016).
- Made an invited presentation entitled, “Update on edge-of-field research and conservation practice assessment,” at the Conservation Tillage Conference in Ada, OH (3/3/2016).
- Made an invited presentation entitled, “The role of tile drainage in phosphorus transport and the impact of gypsum, cover crops, and drainage water management in reducing losses,” at the Healthy Soil – Healthy Waters meeting.
- Made presentation entitled, “Edge-of-field research: what is the data telling us right now?” at the Western Lake Erie Basin stakeholder meeting in Columbus, OH (3/22/2016).
- Made presentation entitled, “Update on edge-of-field research approach and findings,” and gave a field tour at the Ohio State University Extension Day in London, OH (3/29/2016).
- Provided illustrated lecture in the Research and Extension Track session on Small Farm Systems to Central State University, Cooperative Extension Program, 2016 Minority, Women, Veteran and Small Farmers Conference, Dayton, OH (4/9/2016).
- Made presentation entitled, “Northwest Ohio Crop Yield Benefits with Agricultural Water Recycling and Sub irrigation Based on Future Climate Scenarios.”

- Provided field presentation entitled, “Watershed and Edge-of-Field Research,” to Ohio State University graduate students and faculty in Centerburg, OH (5/13/2016).
- Made presentation entitled, “Edge-of-field research: past, present, future,” at the North Central Extension & Research Activity (NCERA) -190 Precision Ag Group meeting, London, OH (5/17/2016).
- Made presentation entitled, “Watershed and Edge-of-Field Research: What is the data telling us now,” at the Natural Resources Conservation Service (NMRCS) Area 5 Meeting in Delaware, OH (6/13/2016).
- Made presentation entitled, “Evaluating the 4R Nutrient Stewardship Concept and Certification Program in the Western Lake Erie Basin,” at the 4R Summit in Indianapolis, IN (6/15/2016).
- Made presentation for a delegation of Russian scientists, entitled, “Community ecology, biomarkers, and ecotoxicology - interdisciplinary insights for understanding the influence of agricultural conservation practices on channelized agricultural headwater streams.”
- Invited to give seminar entitled, “Evaluating the influence of riparian conservation and restoration practices on headwater streams.”
- Consulted with local farmer requesting input on design of drainage system for newly acquired farmland in Fort Recovery, OH (5/6/2016).

- Made presentation entitled, “Hydrology and water quality associated with drainage water management,” at Nutrient Management Field day sponsored by Ohio State Extension at the Northwest Agricultural Research Station of Ohio Agricultural Research and Development Center (OARDC) in Hoytville, OH (7/28/2016).
- Provided edge-of-field research summary at Seneca County Field Day to approximately 30 producers (8/16/2016).
- Provided edge-of-field research summary to 30 elected officials and producers at Crawford County Elected Officials tour (8/23/2016).
- Provided edge-of-field research summary and recommendations to 75 producers in Hardin and surrounding counties (8/26/2016).
- Made presentation entitled, “Using edge-of-field research to assess agricultural management practices,” at State of Science: Harmful Algal Bloom conference in Toledo, OH (300 stakeholders) (9/15/2016).
- Made eight field day presentations (Eedge-of-field research to address nutrient loss) at Farm Science Review, London, OH (100 producers and stakeholders) (9/21-23/2016).
- Provided consultation to Michigan Corn Growers, Michigan Agribusiness, and Michigan Farm Bureau on edge-of-field findings and provided guidance on practices to reduce nutrient movement from agricultural lands (9/30/16).

Oklahoma:

**Fort Keogh**

- Stakeholder meeting, about 19 people attended.

**Hydraulic Engineering Research Unit**

- Co-hosted informational booth with U.S. Natural Resources Conservation Service (NRCS) at the Association of State Dam Safety Officials (ASDSO) Annual Meeting in Philadelphia, PA.
- Hosted informational booth at the Oklahoma Association of Conservation Districts State Meeting in Midwest City, OK.
- Co-organized and co-taught Design of Stepped Spillway Hydraulics Workshop at the International Symposium of Hydraulic Structures in Portland, OR.
- Hosted research experience for undergraduate student from Oklahoma State University, Stillwater, OK.
- Hosted tour for undergraduate students and advisor from Langston University, Langston, OK.
- Hosted tour for U.S. Natural Resources Conservation Service (NRCS) new employees and

instructors from various locations across the United States.

- Hosted tour for faculty, research engineer, and post-doctoral student from Oklahoma State University.
- Hosted tour for engineers from the U.S. Army Corps of Engineers, Tulsa District.
- Hosted tour for high school students from the Choctaw Nation Jones Academy as part of the Ohio State University Experimental Program to Stimulate Competitive Research (EPSCoR) STEM Experience (July 12, 2016).
- Invited speaker for Cameron University Stem Academy, Lawton, OK.
- Hosted Oklahoma Conservation Commission, National Watershed Coalition, and NRCS to film research flumes for training videos.

#### **Wheat, Peanut and Other Field Crops Research Unit**

- Organized and moderated the Oklahoma Peanut Expo in Altus, OK.
- Hosted tour for undergraduate students and advisor from Langston University, Langston, OK.
- Organized and delivered peanut research results for annual field day, Fort Cobb, OK.

Oregon:

**Horticultural Crops Research Unit**

- ARS scientists presented results from research on alternatives to soil fumigation for the management of soil-borne pathogens. The field day was organized as a collaborative effort between ARS (Oregon) and Washington State University.
- Chaired the Grapevine Improvement Committee composed of nurserymen, Oregon State Department of Agriculture, Oregon State University, vineyard managers, consultants, and owners with 25 people in attendance. Developed a plan to provide information on grapevine red blotch virus, *Xylella*, and the importance of sourcing clean plants.
- Presented information on blueberry fruit drop virus and other viruses of blueberry important in Washington at the Northwest Berry Conference in Lynden, Washington. Approximately 100 people attended.
- Robert Martin participated in the Grape Pest Strategic Management Plan Meeting for the Willamette Valley to discuss priority pests of grapevine in Oregon. Approximately 25 growers present.
- On-site nursery tour to see various biological control practices, brought natural enemies to train growers to identify important beneficials.

- Presented research results to 40 strawberry growers, packers, processors, and farm advisors at Oregon State University North Willamette Research and Extension Center.
- Presented research results to 60 blackberry and raspberry growers, packers, processors, and farm advisors at Oregon State University North Willamette Research and Extension Center.
- Presented research results to 125 blueberry growers, packers, processors, and farm advisors at Oregon State University North Willamette Research and Extension Center.
- Toured breeding plots at Oregon State University North Willamette Research and Extension Center and discussed potential of advanced selections and cultivars of berries and kiwi developed in our program.
- Presented research results to 40 red raspberry growers, packers, processors and farm advisors at the WSU Raspberry Machine Harvesting Field Day in Lynden, WA.
- Presented growth and harvest information to 12 participants in Commission sponsored "Berry Camp."
- Scientist from HCRU in Corvallis, OR, presented information on grapevine red blotch virus to grape growers and vintners. Approximately 80 growers, consultants, associations' members, and Oregon Department of Agriculture staff attended.
- Provided information on important viruses of grapevine in Oregon to the Oregon Wine Board

Research Committee in preparation for their developing a grant “Request For Application”.

Approximately 40 people attended.

- Hosted Oregon grower who was interested in identifying potential cultivars for planting in a root rot site. Grower left meeting with options for planting in his field.
- Hosted a field day in conjunction with collaborating grower at their vineyard. Demonstrated equipment used to study air turbulence and pathogen dispersion and discussed plant disease modeling.
- ARS scientist presented results from research on soil fumigation alternatives for the management of soil-borne pathogens in forest nurseries. Research was presented on pathogen movement between nurseries, biocontrol failure, and how to mitigate risks associated with pathogen movement. Meeting was attended by 70 growers from 9 States.
- Presented results for the latest surveys for fungicide resistance and advised growers on how to manage grape powdery mildew with fungicide resistance.
- Discussed with representatives of the Climate Corp. and Monsanto the development of cyber-physical systems as decision aides and the potential for collaboration.

### **Forage Seed and Cereal Research Unit**

- Provided summaries of experimental data to approximately 50 stakeholders at a "Biochar Expo"

hosted by Biochar Study Group of the Umpqua.

- Provided technical advice and recommendations for improving cleaning of clover and ryegrass seed.
- Presented information on the yellow dwarf viruses and cocksfoot mottle virus infecting orchardgrass seed production fields, which may be contributing to stand decline in the Willamette Valley at the Oregon Orchardgrass Commission meeting, Albany, OR.
- Presented research results to administrators from the USDA Forest Service and local commercial foresters and exchanged information concerning ongoing biochar projects at North Willamette Research and Extension Center, Oregon State University, Aurora, OR.
- Hosted commercial growers from eastern Oregon to present research results and discuss the potential use of biochar to improve garlic yield.
- Presented information on the prevalence of viruses infecting grass seed production fields in the Willamette Valley, and methods for cleaning equipment between infected and non-infected fields to prevent spread of mechanically transmitted viruses.
- Presented research update at the summer meeting of the Hop Research Council held in Boise, ID.
- Presented current research and best management practices for cultural practices at Central Oregon Home and Commercial Agriculture Extension Workshop in Bend, Oregon.

- Co-hosted the Dry Farming Demonstration Days at Oregon State University Center for Urban Agriculture in Corvallis, OR, and presented a talk to approximately 200 stakeholders about the ability of biochar to lower irrigation requirements.
- Co-hosted and presented two talks on the Oregon State University Campus, Corvallis, OR. Led 80 stakeholders, scientists, and biochar producers on a tour of the on-going biochar-related experiments at the Forage Seed Production Research Center. This meeting drew approximately 300 people of which 60 percent were stakeholders, growers, and biochar producers.
- Presented on three talks on best management practices for disease control at Winter Meeting of the Hop Research Council, Palm Desert, CA (1/20/2016); the Indiana Small Farms Conference, Danville, IN (3/3/2016); Disease Management Workshop, Woodburn, OR (2/18/2016); the Washington Hop Growers Association, Yakima, WA (1/8/2016); and the Ryegrass Growers Association, Albany, OR.
- Presented talk on hop genetics and genomics at Michigan State University, East Lansing, MI.

#### **Soil and Water Conservation Research Unit**

- Hosted members from the Pendleton community to see a demonstration of the Yamaha RMX helicopter and tour ARS facilities.
- Hosted growers, consultants, agencies, and university colleagues at the annual field day of the

Pendleton Agriculture Research Center and at the annual field day of the Sherman Station.

Presented research on spring wheat protein response to added nitrogen, and "Crop Residue- Long Term Effects on Organic Matter, Moisture and Microbes."

- Hosted meeting of the liaison committee of Pendleton Agricultural Research Center and presented research information.
- Presented research information of the ARS remote-sensing research program to participants of the Pendleton unmanned aerial vehicle (UAV) test range.
- Presented research information to U.S. Department of Energy (DOE) and USDA scientists and officials at the USDA-DOE research collaboration meeting.
- Presented research information on optical sensing of crop nitrogen to growers and consultants at the Direct Seed Conference.
- Presented research information on managing protein of dryland wheat at the Washington State University Advanced Agronomy Seminar.
- Provided assistance to local growers and compost manufacturers; designed a test of the soil quality under a new tillage method, testing soil quality effects of compost formulations; discussed problems of killing thistles, and discussed management options.
- Presented research information on longevity of effects of soil amendments on microbial

communities to 15 producers and industry representatives.

- Presented research on use of chemical and microbial parameters to predict nitrogen loss in soil to Washington State University staff. Attendees included three producers involved in the experimental plots.
- Hosted the Plant Physiology class from Whitman College for informational tour focused on local farming practices, water limitation, wheat physiology, microbiology, and regional hydrology.
- Conducted a workshop entitled, "Just Catching Some Sun," on photosynthesis. The conference was designed to introduce 5th and 6th grade girls to careers in science, technology, engineering and mathematics (STEM).

### *Pennsylvania:*

#### **Eastern Regional Research Center**

- Hosted students from area schools to provide overviews and presentations of what types of science (research) are conducted at the Center. Also provided encouragement for students to seek a STEM education leading to a career in science April 2016.

#### **Pasture Systems and Watershed Management Research**

- Chaired a session on riparian management at Northeast Pasture Consortium Meeting.

- Organizer/presenter for week-long NRCS Pasture Ecology II course.
- Presented invited talk at the Blair/Huntingdon County Conservation District Field Day (George Lake Farm), Tyrone, PA.
- Presented invited talk on at the USDA Northeast Climate Hub GHG Mitigation Workshop, Beltsville, MD.
- Presented invited talk at a Pennsylvania Association for Sustainable Agriculture (PASA) field day, Newmanstown, PA.
- An exhibit was developed and presented at the Pennsylvania Ag Progress Days demonstrating the flow and loss of nutrients throughout a dairy farm.
- Identify action items and needs for outreach and research for Coal Combustion Residues in the next 5-7 years.
- Consulted with Raven Power in support of their effort to market byproduct gypsum for agricultural use in Maryland and Pennsylvania.
- Consulted with Granco Minerals on the development of markets for a granulated gypsum product for use in reducing phosphorus solubility.

- Gave presentations to a farmer group on the potential impacts of climate change on water resources in the Mid-Atlantic region of the United States.
- Gave presentations to farmer group on the potential impacts of climate change on water resources in the Mid-Atlantic region of the United States.
- Invited speaker at University of Wisconsin Extension Meeting.
- Presenter at meetings with local Maryland farmers discussing applications of Manure Phosphorus Extraction System (MAPHEX) technology.
- Presenter at meetings with local Vermont farmers discussing applications of Manure Phosphorus Extraction System (MAPHEX) technology.
- Provided information to stakeholder group on resources and tools for forage prediction.
- Invited speaker at Pennsylvania Association for Sustainable Agriculture (PASA) Grazing and Climate Change workshop.
- Taught two plant identification courses in Butler County, PA.
- Presented research to a stakeholder group at Tidmarsh Farms, Massachusetts.
- Invited to give presentation on research on pasture productivity and carbon sequestration at

Virginia Tech University.

### *South Carolina:*

#### **Coastal Plain Soil, Water and Plant Research Center**

- Hosted a working group meeting on mine spoil remediation to research plans for the design and use of biochar to remediate mine spoils and mine-impacted soils.

#### **Vegetable Laboratory**

- Hosted coordinating research efforts in the U.S. Agency of International Development (USAID)-sponsored project, “Genomics-guided RNAi Solutions for Whitefly Management in Cassava and World Food Crops.” Training provides technology transfer protocols for the development of RNAi-based products to reduce insect pests and viral pathogens of cassava and other food crops across countries in East Africa.
- Open house in cooperation with Clemson University Coastal Research and Education Center, where visiting customers and stakeholders heard about the research projects focused on a variety of issues related to vegetable production and protection issues of the industry of the southeastern region for solving current problems in production and processing of watermelon, melon, sweet potatoes, broccoli, peppers, leafy greens, and other vegetables.

### *South Dakota:*

#### **North Central Agricultural Research Laboratory**

- Provided a tour and overview of ARS facilities and research program to Lake County leaders and conservationists.
- Hosted community volunteers who assisted in the upkeep and harvest of our People's Garden. Participants learned about rainwater capture, no-till gardening, composting, and other conservation measures.
- Provided an informational and hands-on display of insect pests of South Dakota crops at the National Ag Day celebration in Sioux Falls, SD.
- Scientists provided interviews about sustainable agricultural practices to manage weeds and soil health to be edited and compiled into educational videos in collaboration with Natural Resources Conservation Service (NRCS) and South Dakota State University.

### *Texas:*

#### **Castroville**

- Attended Texas A&M AgriLife Research wheat-breeding program multistate rust evaluation

nursery plots field day on 4/20/16.

### **Cotton Genetics and Genomics Unit**

- Hosted about 70 undergraduate agricultural science students from the Universidad Autonoma Chapingo, Mexico (06/2016). Provided a tour of cotton research and germplasm collection facilities.
- Hosted about 20 students from a Texas A&M University Horticultural Sciences class (02/2016). Focus was on cotton research program and the National Cotton Germplasm Collection, and included a tour of greenhouses and seed vaults.
- Hosted key industry collaborators/cooperators in cotton research and development (07/2016). Provided tours of the National Cotton Germplasm Collection facilities and provided updates on research.
- Hosted potential cotton research collaborators from Baylor University (04/2016), which included a tour of National Cotton Germplasm Collection and overview of current cotton research programs.
- Hosted visiting cotton scientists from several major Chinese Universities (06/2016), which included a tour of the National Cotton Germplasm Collection and overviews of cotton research.
- Hosted cotton collaborators/cooperators from the Texas A&M AgriLife Research Center in

Lubbock, TX. Included updates of ongoing cotton research and tour of the National Cotton Germplasm Collection facilities.

### **Cotton Production and Processing Research Unit**

- We hosted, coordinated, and taught classes on hydraulics, air quality, pneumatics, maintenance, and repair of equipment, safety, first aid, and proper equipment operation to 142 cotton gin personnel from across the United States, a majority of which were minorities.
- Hosted Texas Cotton Ginners Trust and gave assistance in their safety and first aid training/certification of cotton industry personnel. A total of 117 individuals attended the training. A total of four 3-day courses were offered.
- Gave tours to four different groups, two from China, one from Brazil, and one from Northwest Grain Growers Association on our facilities and the research being conducted for a total of 92 people.
- Invited to demonstrate the mechanical delinter technology at the Breeders Tour to cotton breeders from around the world. Ran samples, answered questions, and initiated several ongoing collaborations.

### **Livestock Issues Research Unit**

- Hosted and coordinated a research briefing and tour of our animal research facilities for 15

technical support staff and scientists and numerous other groups and companies.

### **Pecan Breeding and Genetics Unit**

- Hosted a group of about 12 Texas Forest Service personnel and explained the pecan breeding program and provided a tour of facilities and orchards (09/2016).
- Hosted about 15 members of the Texas Pecan Growers Association, Board of Directors (09/16). Gave updated information on pecan research and tour of research orchards.
- Hosted three pecan breeders from Jiangsu, China.

### **Plant Stress and Germplasm Development Research Unit**

- Hosted a seminar on the research being conducted and gave a tour of the lab and sorghum field.

### **Sorghum Genetics and Genomics**

- Hosted sorghum breeders from four commercial sorghum seed companies (07/2016). The participants were briefed on the ongoing Sorghum Reinstated Conversion Program, and were given field tours showing the positive results of that research program.

Utah:

**Forage and Range Research Laboratory**

- Two rangeland tours were hosted for public and private clients that have interest in learning about improved plant materials and management practices for restoration of ecological systems in harsh environments in the Great Basin.
- The FRRL Focus Group Executive Committee (15 attendees) met to discuss aspects of its advocacy for the FRRL and plant improvement research for rangelands, pastures, and turf.
- Provided information to ranchers and government organizations regarding released grass and legume germplasm to improve productivity of sheep and wool production on western U.S. rangelands. (Park City, UT, 140 attendees, 11/5-7/2015; Salt Lake City, UT, 250 attendees.)
- Organized, planned, and carried out a science fair for grades K-5 of a local elementary school in conjunction with the Parent Teacher Organization. A total of 40-45 students presented about 35 projects, which were judged by 20 students from the local high school. Presented science experiments, materials, and ideas to motivate elementary students to participate in a science fair. Approximately 300 people attended.

**Poisonous Plant Research Laboratory**

- Discussed poisonous plants in Cache Valley and their impact on livestock and people; gave tour of poisonous plant garden; taught importance of identification.
- Distributed bulletin 415 to extension agents, veterinary clinics, Scout leaders, Kyrgyz Republic group, and Utah State University students to aid in identifying poisonous plants.

### Washington:

#### **Animal Diseases Research Unit**

- Provided information concerning "Control of Infectious Diseases" at the Domestic Sheep Grazing/Bighorn Sheep Stakeholder Meeting at the Hal Holmes Community Center, Ellensburg, WA.

#### **Horticultural Crops Research Unit**

- Described ongoing research on blueberry fruit drop virus, blueberry scorch virus, and raspberry bushy dwarf virus to growers and consultants in northern Washington field visits. Approximately 20 growers attended.
- Presented the results of blueberry research and discussed future research plans. Informed growers of blueberry selections and new recommended cultivars.

### **Physiology and Pathology of Tree Fruits Research Unit**

- Presentation, "Harvest Maturity and Fruit Quality," at Washington State University Fruit School.
- Posters describing research on apple fruit quality and rootstock pathogen characteristics presented at the annual meeting of the Washington State Horticulture Association.
- Oral and poster presentations on apple tree rootstock disease management and postharvest biology.
- Oral presentation on pear fruit physiological disorder management.
- Oral presentation on tools to manage apple and pear fruit postharvest quality.
- Oral presentation Use of 1-Methylcyclopropene on pears shared with fruit growers, warehouse personnel, consultants, and researchers.
- Information regarding postharvest and fruit quality research shared with Seattle Chamber of Commerce members and staff, industry, and research personnel.

### **Soil and Water Conservation Unit**

- Presented a 50-minute talk to more than 100 growers and agriculture professionals.

### **Wheat Health, Genetics, and Quality Research Unit**

- The Wheat Quality lab held a Wheat Workshop in conjunction with the Washington Grain Alliance and the Idaho Wheat Commission. Approximately 30 growers, wheat commission personnel, and other wheat industry employees participated.
- The Wheat Quality Lab provided tours throughout the year to groups of visiting scientists and stakeholders, including Philippine trade team, the Washington State Crop Improvement Association Seed School, and a visiting scientist from University of Agriculture in Faisalabad, Pakistan.
- The Wheat Quality Lab provided tours and hosted visitors with the Washington Grain Alliance. Visitors to the lab included Nippon Flour Mills; an Indonesian Trade Team from PT Indofood Sukses Makmur; the Nisshin Crop Quality Survey group; and the Korean Trade Team with representatives from Samyang Corporation, U.S. Wheat Associates Seoul office, Daehan Flour Mills, and Cheiljedang.

### **West Virginia:**

#### **Appalachian Fruit Research Station**

- Scientists presented current research projects to tree fruit grower community, with more than 75 growers and Extension educators attending.

- Presented talk highlighting monitoring and management tools for brown marmorated stink bugs at two commercial apple orchard sites.
- Demonstrations of genetic engineering and manipulating stones in plums to visitors from the local Audubon Society.

### **Clarksville**

- New ways of growing blackberries using trellis system and cane training system with 100 attendees.

### **Portland**

- A talk on mechanically harvesting blueberries and methods and modifications needed to reduce bruise damage with 200 attendees.

### **Wisconsin:**

#### **U.S. Dairy Forage Research Unit**

- Presented, “Establishing alfalfa in silage corn” and “Breeding cool season grasses,” to about 80 producers and industry representatives at the Agronomy/Soils Field Day, University of Wisconsin-Arlington Agricultural Research Station (8/31/16).

- Gave a grazing research update to 25 county Extension and Natural Resources Conservation Service personnel at the Team Forage and Grazing In-Service Training (9/13/16).

### **Vegetable Crops Research Unit**

- Presentation entitled, "U.S. Potato Genebank: Service and Research for Potato Genetic Improvement," (1/27-28/2016).
- Two presentations, "New Insights into Cold-Induced Sweetening of Potato" and "Chip Color Defects Promoted by Transient Heat Stress" (8/24/16 - 9/2/2016).
- Update on research funded by local grower organization (7/28/2016).
- Update on research funded by the Chip Committee (7/12/2016).
- Update on research projects and discuss collaborative research plans (2/2-3/2016).
- Meetings with advisory committee for Specialty Crop Research Initiative (SCRI) grants on acrylamide reduction and necrotic viruses (1/12-14/2016).
- Data update on national Specialty Crop Research Initiative (SCRI) project (10/15-16/2016).
- Presentation entitled, "Self-Pollinating Diploid Potato - Lessons Learned" (7/31-8/4/2016).

- Display of carrot breeding germplasm (2/27-3/5/2016).
- Organic and Community Supported Agriculture (CSA) Grower Presentation on carrot breeding (2/9/2016).
- Presentation entitled, "Carrot Improvement for Organic Agriculture" (2/4-6/2016).
- Presentation entitled, "Genetic applied genomic resources for cucumber improvement" (9/5-12/2016).
- Presentations: Progress report of Cucumber Research Team and "Gene Nomenclature for Cucurbit Researchers" (1/9-13/2016).

### **3.10. Technology Transfer Award Winners**

#### **2016 ARS Technology Transfer Award**

*Scientist:* Harvey D. Blackburn, Phillip H. Purdy, Carrie S. Wilson, and Scott F. Spiller

*Lab:* Plant and Animal Genetic Resources Preservation Unit

*Title:* National Animal Germplasm Program

*Award:* ARS Outstanding Award

#### **2016 Federal Laboratories Consortium (FLC) Awards**

*Lab:* Environmental Microbial and Food Safety Laboratory

*Title:* Handheld Imaging Device and Method for Improving Cleaning and Sanitation Inspection of Food Processing Environments

*Award:* National Excellence in Technology Transfer

*Name:* Soil Moisture Active Passive (SMAP) Satellite

*Award:* Interagency Partnership Award

*Lab:* Foodborne Toxin Detection and Prevention Research Unit

*Name:* Improved Detection of Shiga Toxin Through Monoclonal Antibodies

*Award:* Far-West Region, Outstanding Technology Development

**Lab:** Bioproducts Research Unit

**Name:** Encapsulation of Beneficial Soil Microbes in Starch-Gypsum Matrix for Use in Agriculture

**Award:** Far-West Region, Outstanding Commercialization Success

**Lab:** Soil and Water Management Research Unit

**Name:** Waveguide-On-Access-Tube (WOAT) Time Domain Reflectometry (TDR) System

**Award:** Mid-Continent Region, Excellence in Technology Transfer

**Lab:** Bio-oils Research Unit

**Name:** Commercialization of Estolides as a Biobased Engine Oil

**Award:** Mid-West Region, Excellence in Technology Transfer

**Lab:** Cotton Chemistry and Utilization Research Unit

**Name:** Greige Cotton Nonwoven Fabrics for Disposable Diapers

**Award:** Southeast Region, Excellence in Technology Transfer

**Lab:** Quality & Safety Assessment Research Unit

**Name:** Microwave Moisture Sensor for In-Shell Peanut Kernel Moisture Measurement

**Award:** Southeast Region, Excellence in Technology Transfer

**Lab:** Environmental Microbial and Food Safety Laboratory

**Name:** Handheld Imaging Device and Method for Improving Cleaning and Sanitation Inspection of Food Processing Environments

**Award:** Mid-Atlantic Region, Excellence in Technology Transfer

**Lab:** Plant Genetic Resources Laboratory

**Name:** “New Productive, Disease-Resistant Apple Trees”

**Award:** Mid-Atlantic Region, Excellence in Technology Transfer

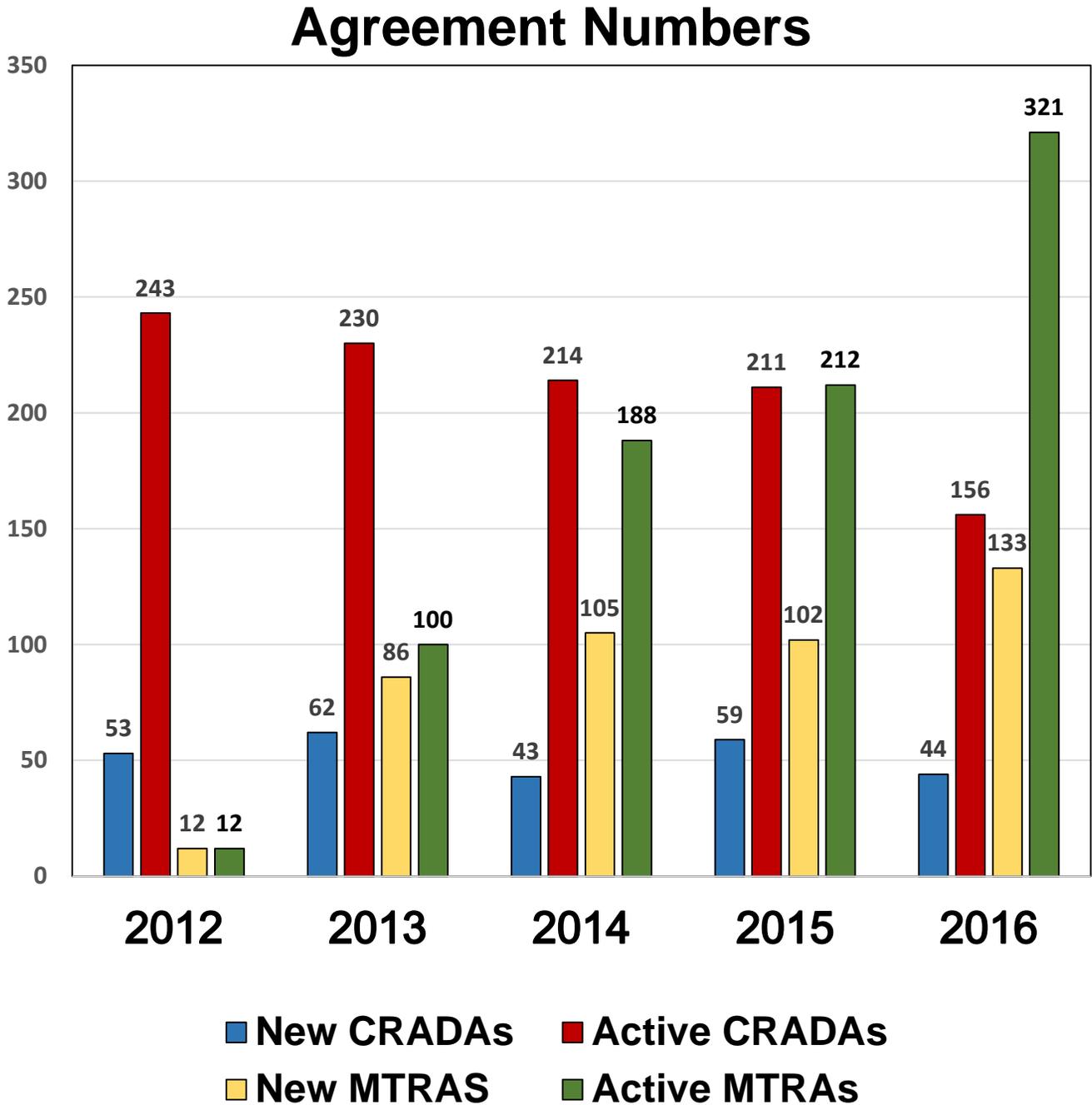
**Lab:** National Center for Cool and Cold Water Aquaculture

**Name:** “Development and Release of a Disease-Resistant Rainbow Trout Line”

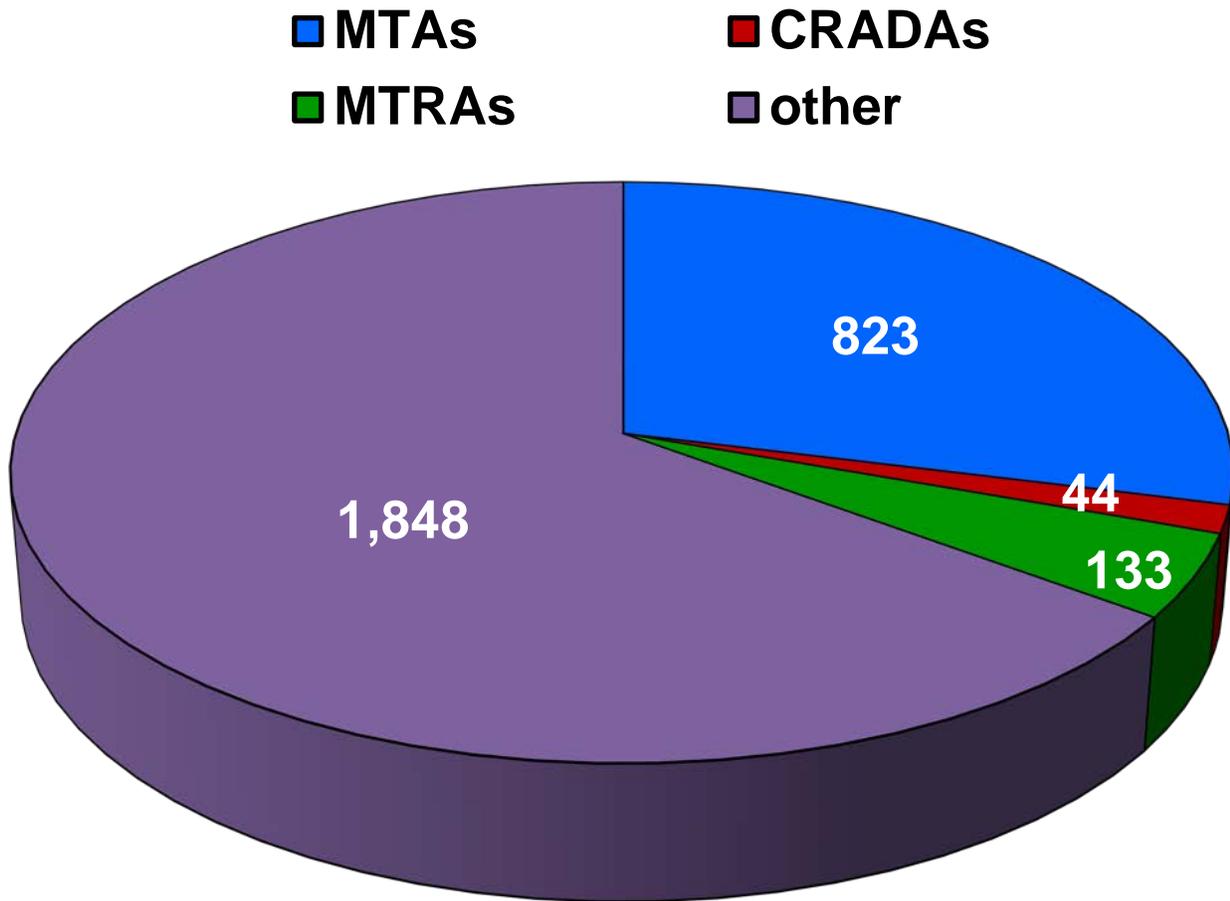
**Award:** Mid-Atlantic Region, Excellence in Technology Transfer

**3.11. Selected Metric Charts.**

**Figure 1.** Number of new and active Cooperative Research and Development Agreements (CRADAs) and Material Transfer Research Agreements (MTRAs). The decreased number of CRADAs is due to the fact that some collaborative research that was previous carried out under a CRADA is now carried out an MTRA.

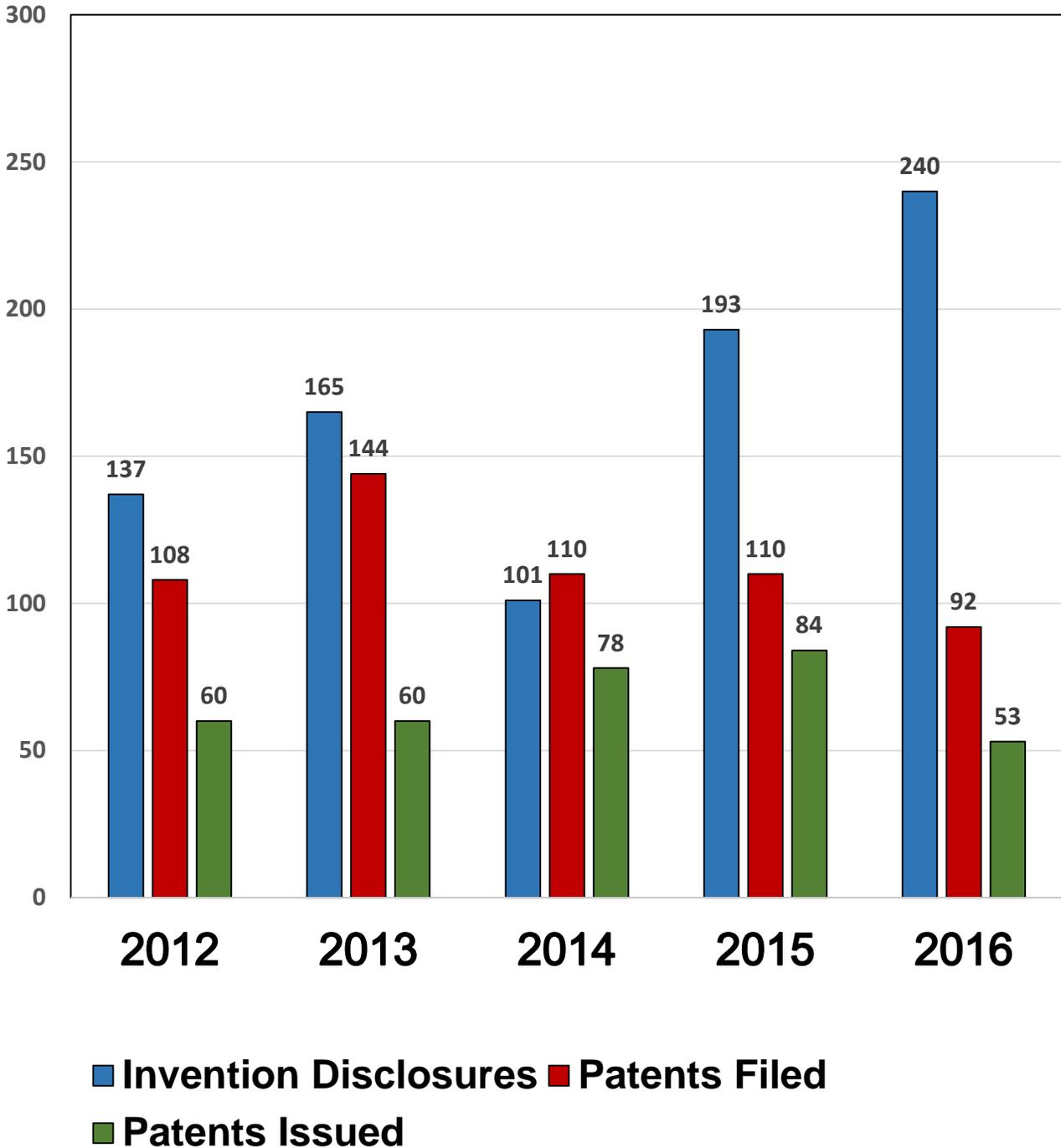


**Figure 2.** Number of collaborative research agreements (Cooperative Research and Development Agreements [CRADAs], Material Transfer Research Agreements [MTRAs], and Material Transfer Agreements [MTAs]) executed by type in FY 2016.



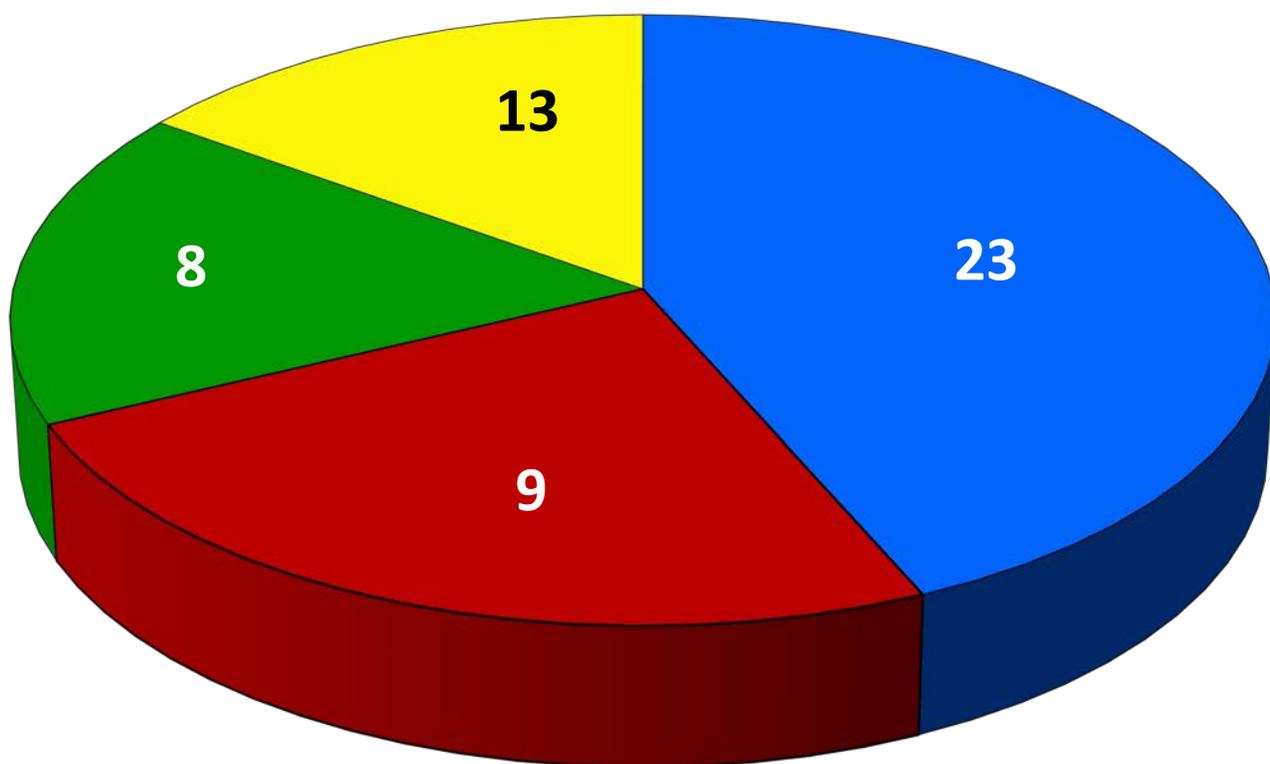
**Figure 3.** Number of invention disclosures, patent applications filed, and patents issued. The year in which a patent issues is not the year in which the patent is filed. The increase in the number of invention disclosures in FY 2016 was the result of adding biological materials disclosures for the first time.

## Patenting Numbers



**Figure 4.** Number of patents issued in FY 2016 by scientific discipline.

- **Life Science**
- **Chemical**
- **Mechanical and Measurements**
- **Plants**



**Figure 5.** Number of license types per year.

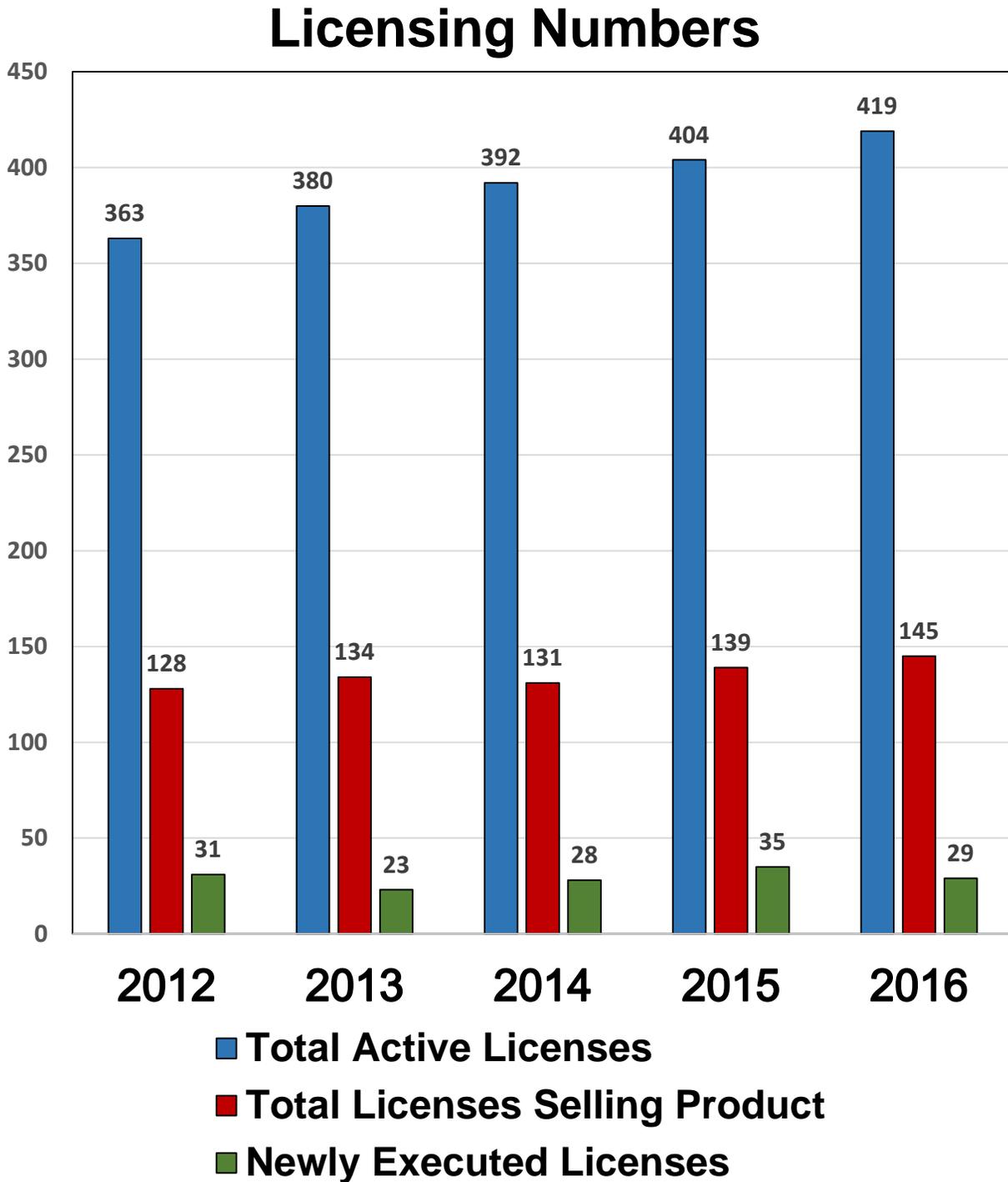
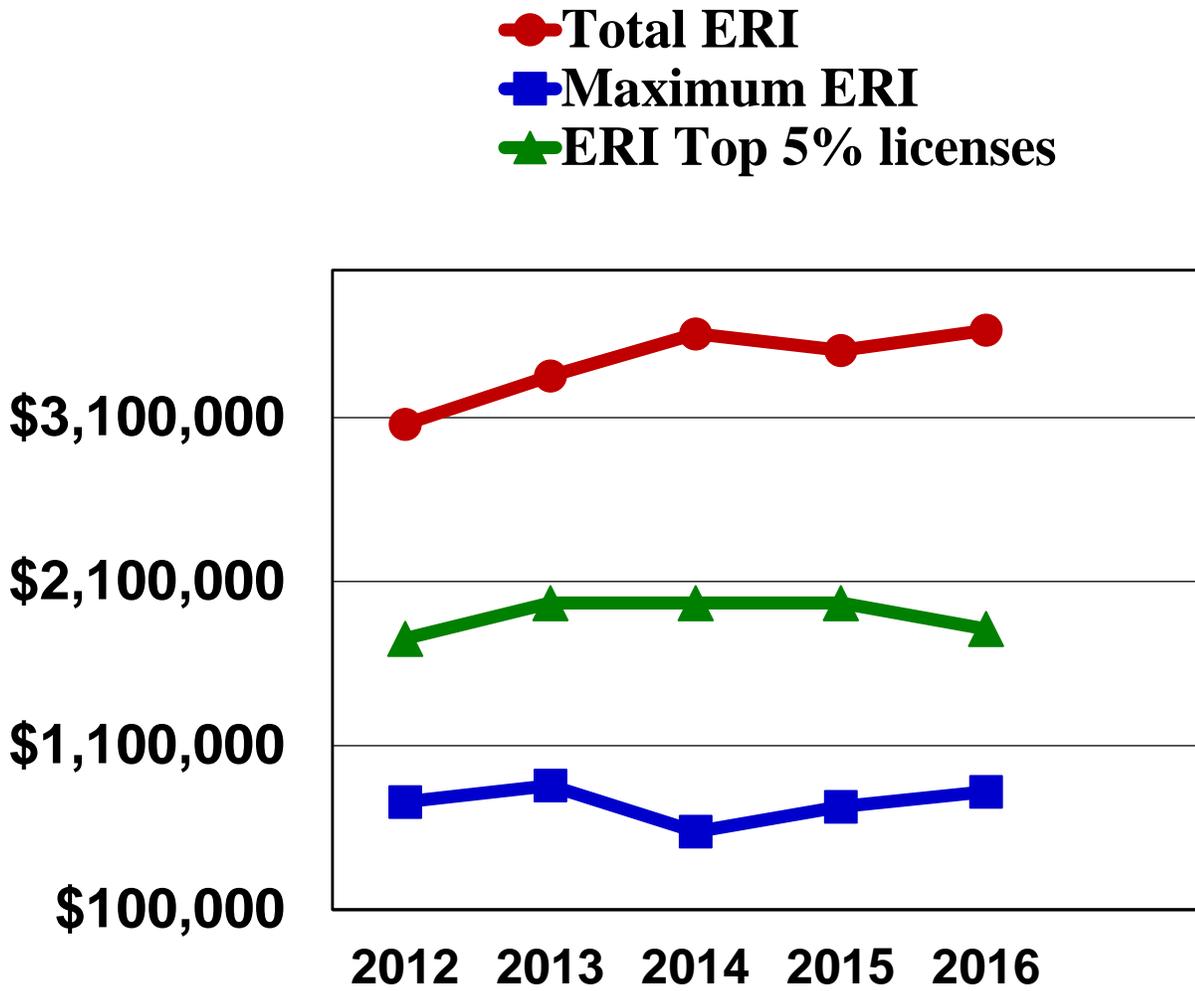
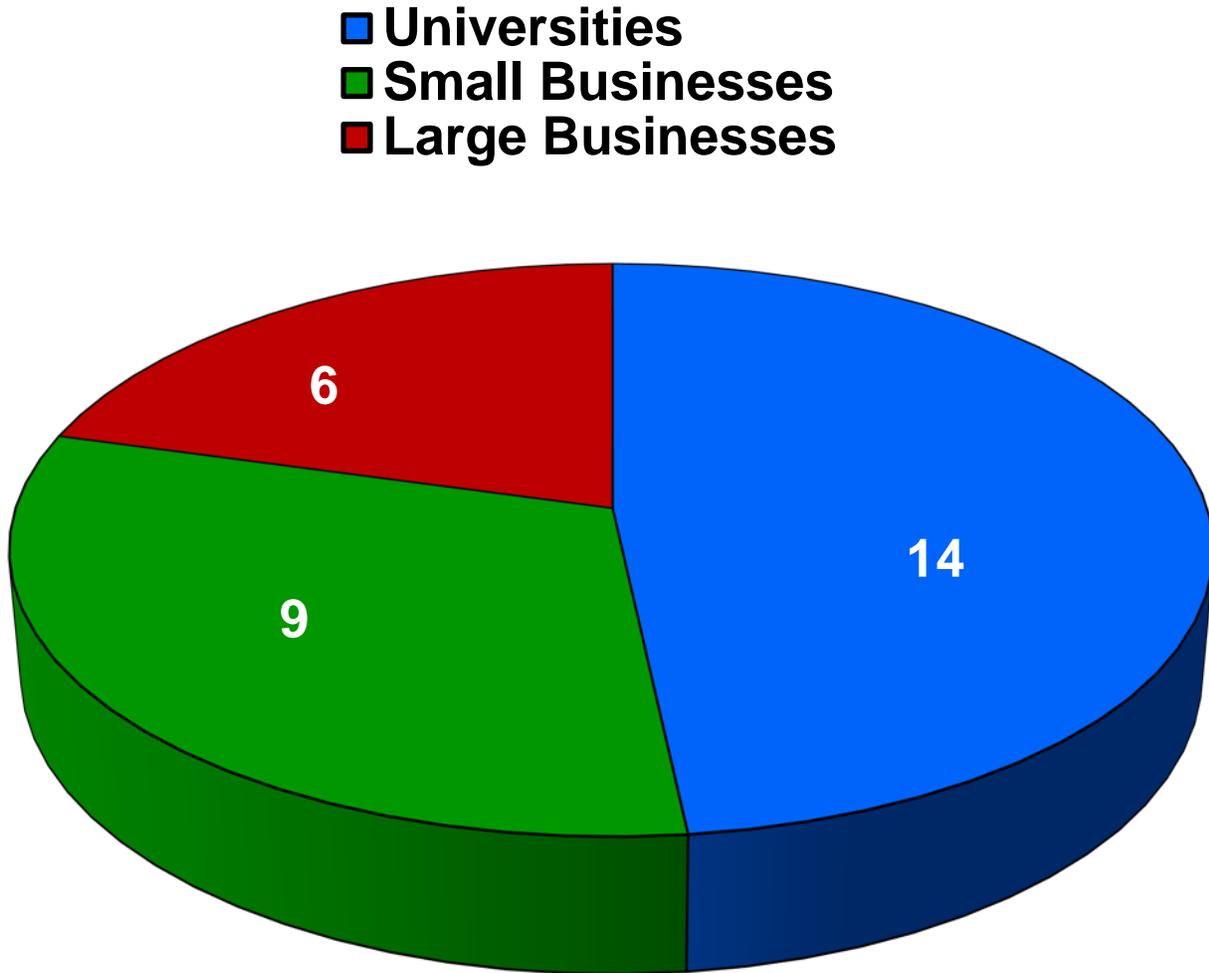


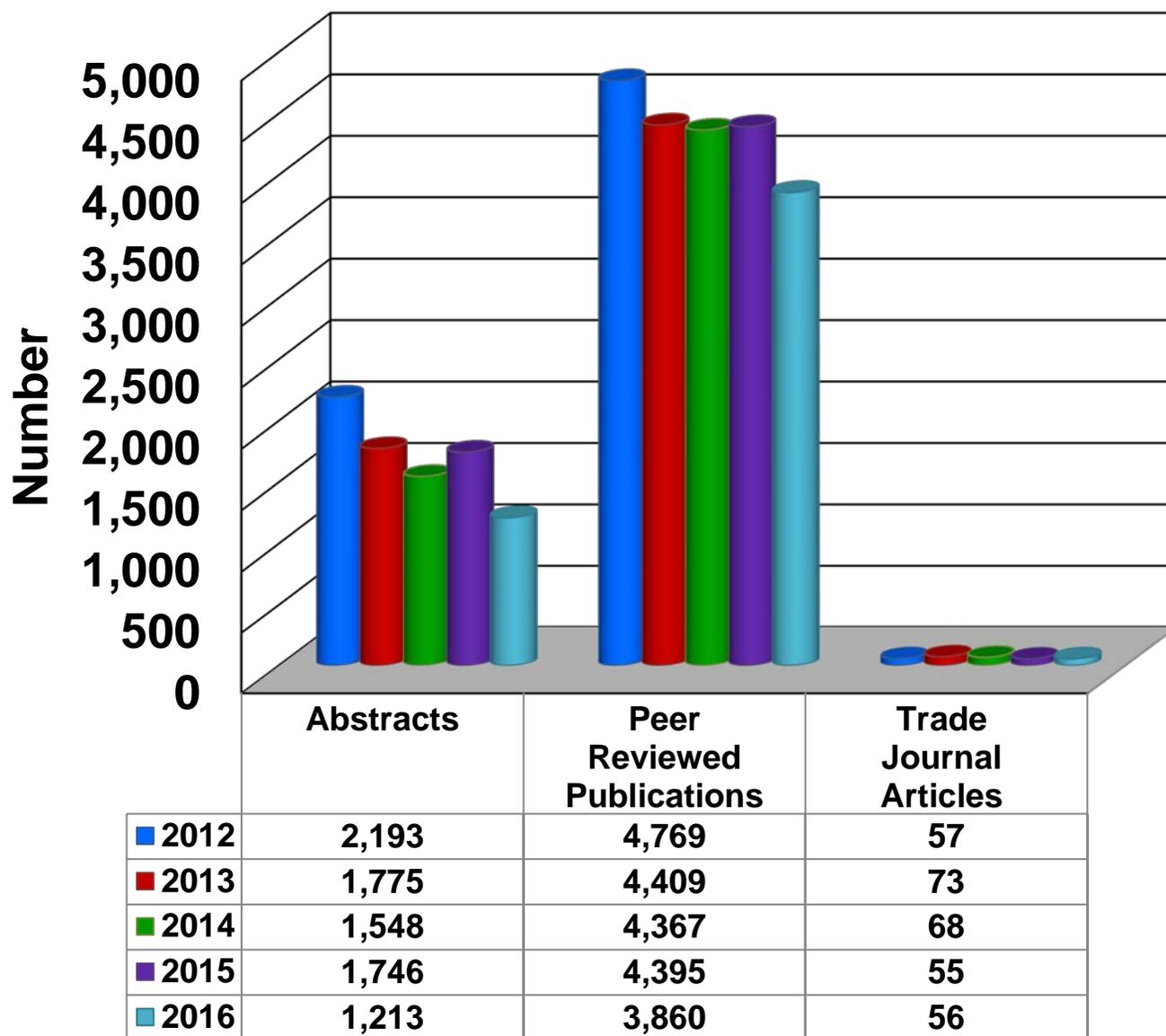
Figure 6. Earned license royalty income (ERI) over time.



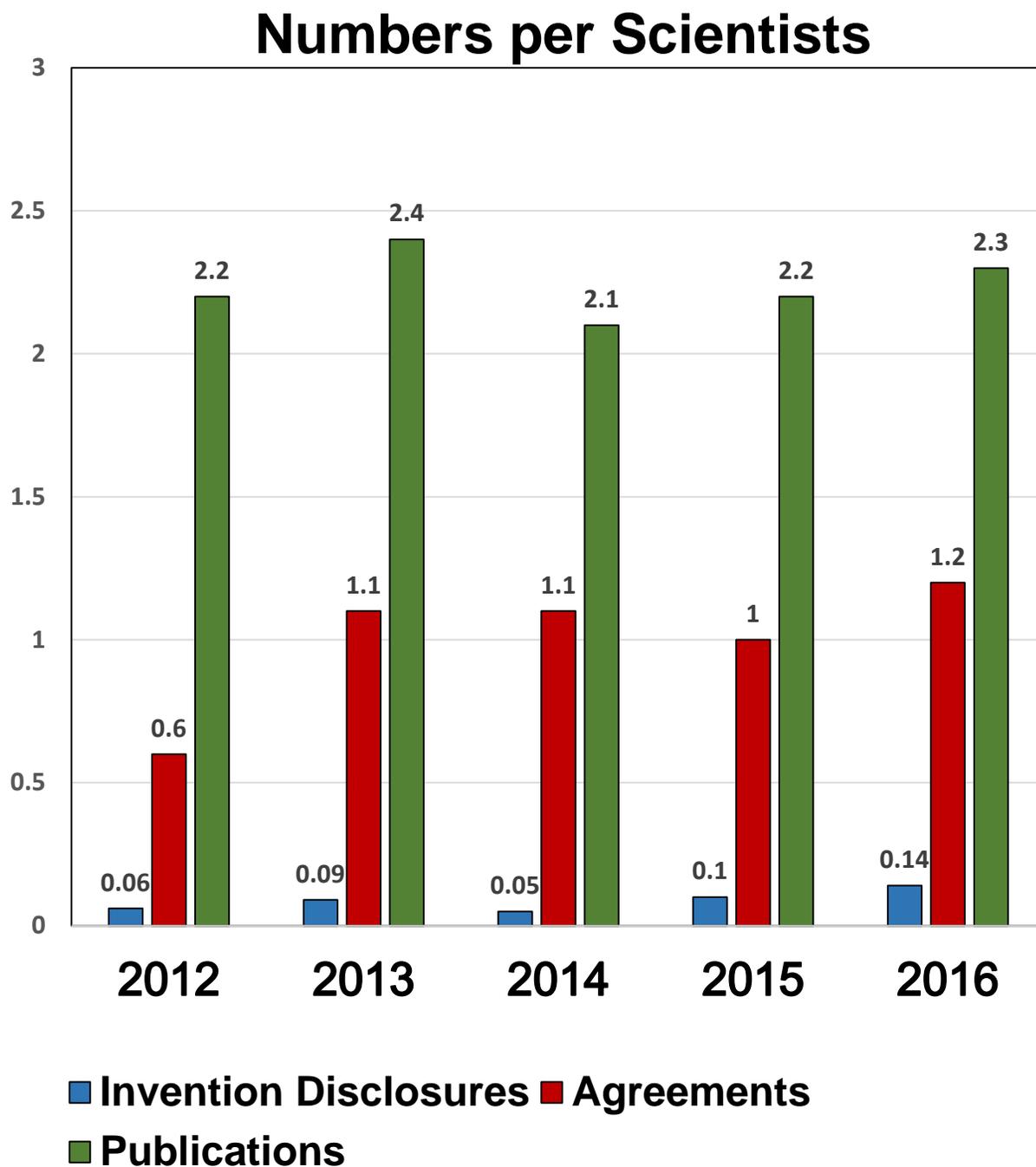
**Figure 7.** The number of new licenses executed in FY 2016 by business type.



**Figure 8.** Number of ARS-approved manuscripts per year.



**Figure 9.** The number of new invention disclosures, new research agreements, and peer reviewed publications per scientist. The rate of publication appears quite stable at 2 to 2.5 peer-reviewed publications per scientist. There appears to be an increasing trend in the number of collaborative research agreements and invention disclosures per scientist over the past 5 years.



## **4.0. Economic Research Service (ERS)**

<http://www.ers.usda.gov/>

### **4.1. Mission Statement**

ERS's mission is to conduct economic research and develop data and statistics that inform public program and policy decisions related to agriculture, food, the environment, and rural development.

### **4.2. Nature and Structure of Research Program**

ERS follows the general USDA definition of technology transfer as the adoption of research outcomes for public benefit. ERS conducts relevant and objective economic research and policy analyses that inform program and policy decisions. ERS designs its research to demonstrate to its customers the consequences of taking alternative policy or programmatic pathways. Our data and market analysis program provides crucial market and trade outlook information to help farmers and agricultural companies run successful businesses and support jobs.

ERS is also the primary source of statistical indicators that, among other things, gauge the health of the farm sector (including farm income estimates and projections), assess the current and expected performance of the agricultural sector (including trade), and provide measures of food insecurity in the United States and abroad. ERS is one of 14 officially designated (by the Office of Management and Budget) Principal Federal Statistical Agencies.

ERS disseminates its research findings, market information, and statistical indicators in a variety of outlets including:

- Its website ([www.ers.usda.gov](http://www.ers.usda.gov));
- Its online magazine, *Amber Waves*;
- Outlook reports for specific [commodity](#) sectors
- [Research and information reports](#);
- [Data products](#), in a variety of forms/formats to suit users' needs; and
- [Refereed journal articles](#), which assure the professional credibility of findings.

ERS is located in Washington, DC, and has about 250 Federal researchers working on socioeconomic research. Additionally, ERS seeks out academic and private-sector collaborators through contracting and cooperative agreements to leverage external expertise to complement the knowledge of our intramural research staff.

#### **4.3. Current Technology Transfer Goals, Objectives, and Measures of Success (Metrics)**

ERS uses a web-centric approach to communication with customers in order to convey clear, objective, and transparent research, data, and analysis to decisionmakers, policy officials, industry, non-governmental organizations, and the general public. All ERS research, data, and other information disseminated by the agency are available through the ERS website. ERS measures customer satisfaction with the ERS website using a survey based on American Customer Satisfaction Index (ACSI). The measure tracks satisfaction of website users and provides a basis for comparison with similar government and private-sector websites. The target for this measure is at or above the average rating for

government websites in the Information/News category.

#### **4.4. Strengthening Current Activities**

ERS continues to enhance and update its website. Following a recent major upgrade, the site is faster and ERS research, analysis, and data are easier to find and are dynamically displayed in multiple locations. The website features more intuitive navigation for customers to enhance information delivery and also features enhanced functionality for mobile users.

#### **4.5. ERS response to Presidential Memorandum on Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Businesses**

In the USDA's implementation plan for the Presidential Memorandum, ERS described an initiative to promote technology transfer and commercialization. The initiative and its implementation in FY 2016 are described below.

**USDA 29: ERS is making wider use of social media and new technologies (such as mobile readiness) to widen and expand the reach of our information services to the general public.**

ERS's wider use of social media and new technologies (such as mobile-responsiveness and open data methodologies) widen and expand the reach of our information services to the general public. ERS has been a leading innovator in support of the Administration's Digital Strategy and Open Data initiatives, providing a wealth of products—including data and information—designed to enhance mission delivery.

In FY 2016, ERS used several new tools designed to help consumers more easily access critical programs and stimulate further innovation:

- **Responsive Design:** ERS optimized its website for mobile users, with mobile-friendly pages that automatically adapt to the user's computer, tablet, and smartphone—without having to pinch or expand. This method also provides internal efficiencies in design/production (versus developing multiple style sheets for individual devices/platforms).
- **APIs** (Application Programming Interface) for select data and geospatial/mapping applications, enabling researchers and developers to build applications using ERS data and process for additional insights.
- **Data Visualization:** New tools and technologies have been adopted to present data in a series of active online charts that allow users to interact with ERS data and design charts that reflect different views of data for an enhanced user experience.

The new products and tools extend and expand access to ERS research findings, market outlook, and data—making the Agency's information more readily available to the general public. These items were a first among USDA (and many Government agencies), enabling USDA to meet its Digital Government Strategy goals to ensure high-value services and systems are available anywhere, any time, and on any device. The work also supports the President's Management Agenda to improve efficiency, share data with entrepreneurs and businesses, and stimulate job growth.

**USDA 30: ERS is exploring new methods for evaluating economic impacts of research collaboration and partnerships between public agricultural research institutions and the private sector.**

ERS began in 2012 a multi-year project to develop metrics to quantify the impact of economic social science research and analysis, including measurements of impact of ERS research as evidenced by media citations, briefings for senior policy officials, citations of ERS research in the scientific literature, and customer use of information published on the ERS website. This initiative is now completed and the new metrics are now a standard component of the ERS report.

#### **4.6. Downstream Outcomes**

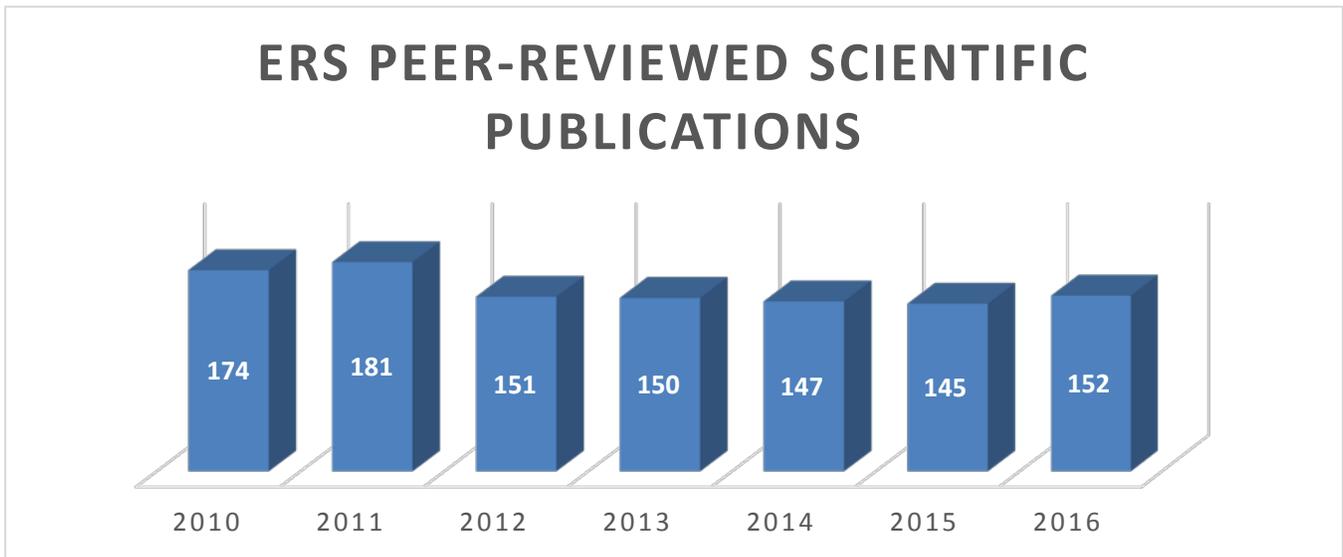
- ERS has developed a unique database from a survey on food purchases and acquisitions by U.S. households – USDA’s National Household Food Acquisition and Purchase Survey [FoodAPS](#). Originally, to protect individual survey respondents’ privacy, access to the data had been restricted to researchers from academic institutions and government agencies. Now, a public version of FoodAPS masks identities of survey respondents to enable access by all interested parties to the valuable data for research and planning. FoodAPS is designed to fill a critical knowledge gap in support of evidence-based approach to Federal food assistance policies and programs. The data are being used to address a range of questions such as where households acquire food in a typical week, which foods they acquire, how much they pay for the food and how the acquired foods match recommendations for a healthy diet.
- Policymakers and the public are provided with easily accessible data on rural areas and issues through the ERS *Atlas of Rural and Small-town America* (<http://www.ers.usda.gov/data->

[products/atlas-of-rural-and-small-town-america.aspx](#)). The online mapping tool provides county-level information on over 110 statistical indicators on the people, jobs, agriculture, and county characteristics of rural (nonmetropolitan) America. The Atlas helps State and local decisionmakers pinpoint the needs of particular areas, recognize their diversity, and develop strategies to build on their assets by using location-based data on population, age structure, race and ethnicity, income, employment, indicators of well-being, and other measures. In fiscal 2016, the Atlas was updated with the most recent information on veterans, education, migration, and income from the American Community Survey. Additionally, the ERS County Economic and Policy Typology Codes that were updated in fiscal 2016 are available in the Atlas.

- Local officials throughout the country can now easily gauge the characteristics of their food environment and target actions that alleviate problems with the availability of healthy food options for the people in their counties or State using the ERS Food Environment Atlas (<http://www.ers.usda.gov/data-products/food-environment-atlas.aspx>). The Atlas includes 211 indicators of the food environments in U.S. counties and States – from the number of fast food outlets per capita, to average food prices for various products, and the rate of obesity. Because ERS determined the location and derived the characteristics of neighborhoods that lack access to sources of healthy and affordable food, national, State and local governments can target food access investments so that people with low access will have better choices and better access to healthy, affordable food.
- ERS’s Twitter feed continues to expand our reach: with nearly 24,000 followers signed up for our tweets in fiscal 2016 – up from 22,000 followers in 2015 and 16,000 in 2014.

- ERS has expanded the use of webinars as a way to more directly connect to customers at the time of release of new research and data. As part of our *ERS Insights* Webinar Series, ERS presented nine webinars in FY2016 on topics including farm income, rural America, and domestic and global food security. These webinars both inform our audiences about complex topics in an easy-to-understand format, and also allow the audience to ask our economic experts questions. Audiences typically include media, agricultural policy staff, agricultural and financial industry analysts, interest groups, non-profits, and academia. On average, about 100 people participate in each of these webinars and ERS records, close-captions, and transcribes each webinar before posting them all on our website for those who want to view them later.

#### 4.7. Publications



## **5.0. Foreign Agricultural Service (FAS)**

<http://www.fas.usda.gov/>

### **5.1. Mission Statement**

The Foreign Agricultural Service (FAS) links U.S. agriculture to the world to enhance export opportunities and global food security.

### **5.2. Nature and Structure of Program**

FAS Washington, D.C., staff and a global network of 96 offices with Foreign Service Officers and locally engaged staff cover over 160 countries. FAS supports U.S. foreign policy, identifies problems, provides practical solutions, and works to advance global food security and opportunities for U.S. agriculture. Within USDA, FAS serves as the principle coordinator of international activities, drawing on the broad expertise of USDA and U.S. agricultural organizations.

#### Trade Policy

FAS expands and maintains access to foreign markets for U.S. agricultural products by providing expertise in international trade policy negotiations and enforcement, and in working to reduce or eliminate technical barriers to trade and sanitary and phytosanitary trade restrictions. FAS works closely with other USDA agencies, Federal and State governments, the U.S. agricultural industry, foreign governments, and international organizations to help ensure a level playing field for U.S. agricultural products in the international marketplace.

### Market Development and Export Assistance

FAS partners with more than 75 cooperator groups, representing a cross-section of the U.S. food and agricultural industry, and manages a toolkit of market development programs to help U.S. exporters develop and maintain markets for hundreds of U.S. products. FAS also supports U.S. agricultural exporters through export credit guarantee programs and other types of assistance.

### Data and Analysis

FAS's network of global contacts and long-standing relationships with international groups contribute to the agency's unique market intelligence capacity for all major agricultural commodities. FAS collects data, and its analysts generate objective intelligence on foreign market opportunities, prepare agricultural production forecasts, assess marketing opportunities for U.S. exports, and both identify and monitor changes in policies affecting U.S. agricultural exports and imports. Agricultural markets and key private-sector constituents rely on FAS data and analyses to develop and implement domestic and international programs and make business decisions.

### Capacity Building and Development

FAS leads USDA's efforts to help developing countries and emerging market economies improve their agriculture and food systems and build their agricultural development and trade capacities. FAS administers international fellowships and other agricultural science and trade technical assistance,

including non-emergency food assistance programs to help meet recipients' nutritional needs and support agricultural development and education.

### **5.3. Response to Presidential Memorandum on Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Businesses**

**USDA 31: Engage in consultation with the Agricultural Research Partnerships Network to assist in establishing U.S. commercial partners with foreign entities.**

FAS continued coordination with the ARS/Office of Technology Transfer to engage ARP Network members that were interested in establishing commercial partnerships with foreign entities. FAS developed relevant guidance and talking points that the ARS/Office of Technology Transfer routinely disseminated to ARP Network members that were interested in consulting with FAS. This initiative is completed.

### **5.4. Downstream Outcomes**

The following summaries illustrate how FAS international trade and capacity building programs supported U.S. technology transfers.

#### **Technical Assistance for Specialty Crops.**

The Technical Assistance for Specialty Crops Program (TASC) invested in the development and transfer of innovative USDA post-harvest irradiation phytosanitary treatments for U.S. specialty crops, like

fruits, tree nuts, vegetables, and greenhouse and nursery crops. In 2015 TASC funded USDA Agricultural Research Service (ARS)-Hawaii to continue working on a project to develop and transfer such irradiation phytosanitary treatments. Their project involves collaborations with grower groups, exporters, the irradiation industry, and relevant university research groups, resulting in treatment protocols for spotted wing drosophila, light brown apple moth, and European grapevine moth and new information on the radiation tolerance-levels of several invasive ants. ARS-Hawaii also received a TASC grant in 2015 to work on the development and testing of a low-cost cabinet X-ray tube machine for phytosanitary irradiation treatments of sweet cherries. The final designs for a packing line scale X-ray tube machine were developed in collaboration with Applied Energy Devices, LLC (Albuquerque, NM) and a prototype was tested for dose uniformity, dose rate, and treatment efficiency. Once foreign approvals are finalized, the X-ray tube machine will be used to irradiate sweet cherries for export. These TASC investments in ARS research were critical in helping U.S. exporters preserve a \$12 billion annual market for U.S. exports of specialty crops. By collaborating with sister USDA agencies, U.S. universities, and specialty crops industries to develop and commercialize post-harvest phytosanitary irradiation treatments, TASC directly helped to promote the transfer and commercialization of these new technologies and, overall, expand the variety, quantity and value of U.S. specialty crops for export markets. With TASC's support, the development, transfer, application, and commercial value of irradiation phytosanitary treatments are expected to continue increasing over the coming years.

**Norman E. Borlaug International Agricultural Science and Technology Fellowship Program.**

In FY2016, the Norman E. Borlaug International Agricultural Science and Technology Fellowship Program (BFP) supported 34 Fellows to help transfer agricultural science and new U.S. technologies to developing countries. Since the Program's inception in 2004, BFP provided training to more than 780

Fellows from 64 countries. Many Fellows and their U.S. mentors maintain ongoing relationships to promote the adoption or commercialization of U.S. technologies in their respective countries. For example, in December 2015, a BFP alumnus leveraged his fellowship at Iowa State University to design, fund and conduct the first successful transfer of a calf embryo in the Republic of Kosovo. The project identified suitable embryos that were purchased from the United States and then implanted in surrogate cows in Kosovo. This technology will continue to improve the genetic makeup of the Kosovar dairy herd, which in turn will positively impact dairy production in Europe's newest independent nation. In Vietnam, a BFP alumnus utilized training from her 2015 fellowship at Mississippi State University to lead her lab at the Institute of Animal Sciences for Southern Vietnam to comply with the testing and calibration requirements of the European Commission Standards, which enabled the lab to submit a 2016 application for technical committee of the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) 17025 accreditation. With this accreditation, the lab will test a wide range of agricultural products for import and export purposes, including issuing sanitary and phytosanitary testing certifications that are internationally recognized. These exemplary Fellows, their U.S. mentors, and other BFP participants are continuing to learn, disseminate, and apply U.S. technologies to improve agricultural sciences, trade, and food security throughout the developing world.

### **Global Partnership for Pesticide Standards.**

Residue data for establishing trade standards (i.e., Codex Alimentarius) pesticide maximum residue levels (MRLs) for fruit and vegetable crops are mostly generated in the United States and other industrialized nations. Therefore, many of the tropical crops grown in developing countries do not have

MRLs and accordingly face international trade barriers due to residue violations in destination markets. The lack of MRLs for high-valued specialty crops from developing countries can have a significant economic impact, especially when exporters are excluded from potentially lucrative markets. To help address this problem, FAS is leading a Global Residue Project to establish an infrastructure and process whereby field trial residue data for crops most commonly grown in developing countries are generated and used to establish MRLs. The Project is working with stakeholders in 20 partner countries in Africa, Asia, and the Western Hemisphere, where national research teams collaborate on joint residue trials, based on study protocols and technology models developed by the USDA-funded IR4 Project. In 2017 FAS and the IR-4 Project will host the third Global Minor Use Summit to review progress and identify additional joint projects, expand partnerships, and continue transfer of knowledge and information about safe crop protection. By transferring these policy concepts and technical skills to foreign partners, the Global Partnership for Pesticide Standards has continued complementing the IR-4 Project by supplementing U.S.-generated data and, in some cases, completely shifting the field trial responsibilities for generating pesticide data to partner countries. In addition to economizing U.S. resources for development and commercialization of pesticides, the Global Partnership continued to promote common standards among the U.S. and foreign agricultural trading partners and, overall, provide modern pest control tools that may be safely used by growers world-wide.

### **Aflatoxin-Reducing Technologies in Africa.**

FAS continued to facilitate vital linkages among the U.S. developers of an aflatoxin-reducing technology, African governments, donors, and other public and private sector stakeholders. This technology, registered as Aflasafe, is a microbial biological control agent that reduces aflatoxin levels in susceptible crops by inducing native, non-toxin-producing strains of *Aspergillus flavus* fungus that

outcompete the toxin-producing strains. Developed by USDA-ARS in collaboration with University of Arizona scientists, Aflasafe was introduced to Africa through a partnership with the International Institute of Tropical Agriculture, where treatments reduce aflatoxin levels by 80 to 99 percent in the harvested product (e.g., maize, groundnut) compared with untreated crops. In 2016, The Permanent Interstate Committee for Drought Control in the Sahel (*Comité Permanente Inter-État de Lutte contre la Sécheresse au Sahel*, CILSS) granted a 12-country registration for Aflasafe SN01 to control aflatoxin contamination on maize and groundnuts in CILSS member countries and, as a result, efforts for large-scale commercial production of Aflasafe SN01 began. Similar products are registered in Kenya and Nigeria and are nearing registration in other African countries. With robust education and marketing, Aflasafe has potential to improve the safety of staple foods consumed by over 126 million people in Africa and, likewise, help African farmers who adopt Aflasafe increase their trade profitability through better compliance with aflatoxin residue trade standards.

## **6.0. Forest Service (FS)**

<http://www.fs.fed.us/>

### **6.1. Mission Statement**

The overall mission of the FS is to “sustain the health, diversity, and productivity of the nation’s forests and grasslands to meet the needs of present and future generations.” Established in 1905, FS is an agency of the U.S. Department of Agriculture (USDA) that directly manages 193 million acres of public land in national forests and grasslands and works with State forestry agencies and other partners to assist in managing 491 million acres of State and private forest lands. It is the only land management agency in USDA. Gifford Pinchot, the first Chief of the Forest Service, summed up the mission of the Forest Service —“to provide the greatest amount of good for the greatest amount of people in the long run.” FS is composed of four areas: National Forest System (NFS), Research and Development (R&D), State and Private Forestry (S&PF), and Business Operations.

The R&D mission is to “develop and deliver knowledge and innovative technology to improve the health and use of the Nation’s forests and grasslands – both public and private.” R&D provides this information to landowners, managers, policymakers, and the American people to help inform their decisions and actions.

## 6.2. Nature and Structure of Research Program



The FS R&D mission area develops and delivers high-quality scientific information, applications, and technology needed by public and private land managers to manage, protect, use, and sustain the natural resources of forests and rangelands. The outcomes of our research include: community protection; multiple environmental and social benefits, such as clean air and clean and abundant water; a great array of recreational opportunities; and a wide range of ecosystem services. Research is conducted by more than 550 scientists and several hundred technical and support staff located at 67 sites across the United States. This structure provides sites for long-term science and management studies of major vegetation types found across the United States. The FS R&D organization includes five research stations (Northern, Pacific Northwest, Pacific Southwest, Rocky Mountain, and Southern), the Forest Products Laboratory, and the International Institute of Tropical Forestry in Puerto Rico. There are also two Technology and Development Centers run by NFS located in Missoula, Montana, and San Dimas, California.

The research program is organized into seven Strategic Program Areas: wildland fire and fuels; resource management and use; wildlife and fish; recreation; water, air, and soil; inventory and monitoring; and

invasive species. Special emphasis areas are: adaptation to climate change, biomass to energy, watershed restoration, urban natural resource stewardship, and nanotechnology.

FS R&D maintains a vital network of 81 Experimental Forests and Ranges, 29 of which were established in the 1930s. Long-term records from some of these forests can provide unprecedented insights into global climate change, watershed function, disturbance recovery, and many other areas. Major research themes include: developing systems for management and restoration of forests, range lands, and watersheds; investigating forest and stream ecosystems; characterizing plant and animal communities; and observing and interpreting long-term environmental change.



### 6.3. Current Technology Transfer Goals, Objectives, and Measures of Success (Metrics)

The FS uses many means of technology transfer, including marketing efforts at tradeshow and with universities; patents; webinars; workshops; social media posts; conservation education and citizen science; public outreach; and publications. Many metrics associated with these efforts are currently being tracked, and FS plans to track new metrics such as social media, web hits, and citation indexes within the next 5 years.

One measure of success currently used by FS R&D is the Customer Satisfaction Survey sent out every 3 years to individuals and groups who use our research information and products. The survey uses econometric models developed collaboratively with FS R&D staff and customized for our products and services. The results are presented as a score based on the American Customer Satisfaction Index methodology, which enables users to compare the scores of other Federal R&D agencies. The three main components measured were relevant activities in each area that drive customer satisfaction, satisfaction itself, and desirable customer behaviors and outcomes. The FY 2015 survey scored 76 percent. Although this marked a 3-point decline from the previous FY 2012 measure, it was above the baseline score of 72 from the initial survey in 2006. The FY 2015 score was also above the Federal average of 64. Results from this survey will be incorporated into FS R&D program planning to show where we excel and how we can improve. This survey is required to meet Agency and Department goals, and will be repeated in 2018. The following table illustrates trends in FS R&D performance outcomes.

<b>Performance measure</b>	<b>FY 2009 - 11</b>	<b>FY 2012-14</b>	<b>FY 2015-17</b>	<b>FY 2018-20</b>	<b>FY 2021-23</b>
Customer satisfaction index score (60,000 – 80,000 customers surveyed every 3 years)	75	79	76		

The principal contact for technology transfer via patents and licensing within the FS is the Patent Program, which reports to the Washington Office and is located at the Forest Products Laboratory in Madison, Wisconsin. The FS Patent Program receives and tracks all invention disclosures, providing guidance to scientists regarding all aspects of intellectual property protection. The Patent Program directs prior art searches and prepares FS invention disclosures for review by the FS Patent Review Committee (PRC), a multidisciplinary committee with members from R&D, NFS, and S&PF. The Patent Program also oversees contract law firms drafting patent applications, and files and prosecutes applications in the U.S. Patent and Trademark Office. Draft patent licenses are prepared by the FS Patent Program and reviewed by ARS Office of Technology Transfer (OTT) Licensing Specialists. CRADAs and other technology transfer agreements for the FS are handled by the FS Grants and Agreements Specialists, with patent marketing responsibilities falling to the FS Patent Program.

The PRC meets bimonthly to evaluate and decide whether to file patent applications on FS invention disclosures. The criteria used by the committee include the invention's relationship to the overall mission of the Forest Service, its potential to further national forest resource goals and objectives, the advancement of the state of the art, and economic concerns such as market potential, costs of production, and licensability. Once the decision to patent an invention has been made, the FS Patent Program handles filing and prosecuting patent applications, and/or working with the joint owner (such as CRADA cooperator or university) to pursue patent protection.

#### **6.4. FS response to Presidential Memorandum on Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Businesses**

In the USDA’s implementation plan for the Presidential Memorandum, FS described six initiatives to promote technology transfer and commercialization. The initiatives and their FY 2015 updates are described below.

**USDA 14: Accountability of Scientists and Engineers in Technology Transfer Accomplishments**

In 2012, the annual performance standards for scientists’ evaluations were revised to include technology transfer elements. In FY 2014, two new performance metrics, Science Delivery Products and Science Delivery Activities, were deployed to measure technology transfer performed at each station. Science Delivery Products, such as non-refereed publications, software, web, and multimedia products, enhance the usefulness of scientific information. Science Delivery Activities, such as workshops, communicate the usefulness of scientific information to users.

<b>Performance measure</b>	<b>FY 2012</b>	<b>FY 2013</b>	<b>FY 2014</b>	<b>FY 2015</b>	<b>FY 2016</b>
Science Delivery Activities	NA	NA	1,224	2,514	2,744
Science Delivery Products	NA	NA	429	442	310
Science Delivery Total	NA	NA	1,653	2,956	3,054

**USDA 15: New uniform metrics for Forest Service Outcomes**

A major review of all performance metrics was conducted in FY 2014 that resulted in 10 new performance metrics, 5 existing metrics were revised, 3 metrics were retired, and 10 existing metrics were not changed. There were no additional changes to metrics during FY 2015-2016.

The “Chief’s Science Delivery Award” and the National Wilderness Award for Excellence in Wilderness Research Applications were presented in February 2016.

Forest Service periodically assesses the number of citations of scientists' publications as an index of the impact of Forest Service science. These indices are: average number of times FS scientists' papers are cited in Science Citation Index during the previous 10-year period beginning 2 years after publication, average annual number of high-impact papers (papers cited >20 times), and average annual number of very-high-impact papers (papers cited >50 times). As reported by Web of Science, from 2006 through October 2015, publications authored by FS scientists were cited in peer-reviewed scientific journals an average of 14,634 times/year. There were 1,945 high-impact papers and 596 very-high-impact papers for the 10 year period ending in 2015.

**USDA 16: New metrics on research outcomes related to intellectual property (patents)**

FS R&D developed and implemented the Research Information Tracking System (RITS), which became the official FS reporting vehicle for all science publications in FY 2010. RITS improves data quality and consistency, provides transparency to the public, and reduces burdensome data calls. The newest version of RITS incorporates patent data which are connected to related publications on specific technology focus areas. Patent data in RITS have been updated to include the last 20 years of information. Going forward, patent data will be entered in RITS annually. Additional updates to improve the patent portion of RITS are planned for future releases.

**USDA 17: Explore additional ways FS and ARS can work together on intellectual property-related matters**

Cooperative Research and Development Agreements (CRADAs) are widely used within the FS to enable researchers to work with university partners and industry leaders and are drafted by the FS Grants and Agreements Specialists. Recognizing efficiencies that could be gained by having standardized agreement language and procedures, FS has used ARS as a CRADA resource in FY 2014-FY 2016 to assist with CRADA questions. Further collaboration is planned for FY 2017.

**USDA 18: Enhance education and extension outreach efforts**

*Natural Inquirer* is a science education journal based on Forest Service science and written for middle school students. Expanded *Natural Inquirer* products include science journals for upper elementary students, scientist cards for middle and high school students, Readers for K-2, and an informal activity guide for middle school students. All of these products are based directly on Forest Service scientists and their research. In FY 2016, 67,440 *Natural Inquirers*, *Investi-gators*, *Readers*, and *NSI: Nature Science Investigators* were distributed to classrooms, homeschools, and conferences. Over 100,000 scientist cards were distributed, including 65,000 women or minority cards. In total, 160 Forest Service scientists were introduced on the scientist cards. Increase in social media: Facebook: 2 percent; Twitter: 18 percent; and Pinterest: 25 percent. The *Natural Inquirer* Web site had 72,834 unique visitors in FY16, a 25 percent increase over FY 2015. Noteworthy distribution points included the National Science Teachers Association; the Association for Supervision and Curriculum Development; the Women of Color in STEM Conference; the Minorities in Agriculture, Natural Resources, and Related Sciences Conference; Americas for Conservation + the Arts; the Ecological Society's Annual SEEDS

Conference; and the Detroit City School System. All work is accomplished in cooperation with our non-profit partner, the Cradle of Forestry in America Interpretive Association, and the University of Georgia.

<http://naturalinquirer.org>

**USDA 19: Enhance FS interactions with entrepreneurship activities at educational institutions**

FS Patent Program continued working with University of Wisconsin-Whitewater through its Small Business Development Center, in which upper class undergraduate business and entrepreneurship students enrolled in “Consulting for Entrepreneurial Companies” develop marketing plans and ideas for patented FS technologies. Each semester, a single technology is investigated in depth and a marketing report is produced. This report is shared with the FS inventors and, if applicable, joint owners for possible further action. In addition, students are encouraged to consider starting businesses based on the technologies.

FS has also continued to work with University of Wisconsin-Madison MBA students in the “Strategic Management of Innovation” class each spring semester. For this class, a variety of patented FS technologies along with patented technologies from Wisconsin Alumni Research Foundation, the patenting and licensing arm of the University of Wisconsin, are presented to the class at the beginning of the semester. Students are divided into groups of 4-6 students. Each group picks one of the technologies to research and prepare a marketing report. These students are also encouraged to consider starting businesses based on the technologies.

6.5. Metric Tables.

**TABLE 1. Collaborative Relationships for Research and Development.**

\*ND-no data available.

Forest Service (FS)	FY 2012	FY 2013	FY2014	FY2015	FY2016
<b>Total number active CRADAs</b>	22	20	44	79	73
Active traditional CRADAs	22	20	24	26	25
Active non-traditional CRADAs	0	0	20	53	48
Active CRADAs with small businesses	0	0	0	ND	ND
<b>Number newly executed CRADAs</b>	3	10	16	20	33
Newly executed amendments <sup>1</sup>	N/A	6	N/A	13	12
Newly executed traditional CRADAs	3	10	9	7	9
Newly executed non-traditional CRADAs	0	0	7	13	24
Newly executed CRADAs with small businesses	0	0	0	ND	ND
<b>Total number active MTRAs<sup>2</sup></b>	0	0	0	4	7
Newly executed MTRAs	0	0	0	4	5
<b>Total number of active other agreements<sup>3</sup></b>	807	3,179	2,550	1,083	1,274
Newly executed other agreements	63	1,380	701	261	322
<b>Number newly executed MTAs</b>	ND	8	7	3	5
Newly executed outgoing MTAs	ND	8	7	3	5
<b>Total number of analysis publications</b>	3,699	3,460	2,083	2,013	2,022
Peer-Reviewed Scientific Publications <sup>4</sup>	3,049	3,014	1,285	1,151	1,169
Trade Journal Publications <sup>5</sup>	650	446	798	862	853
Abstracts <sup>6</sup>	N/A	N/A	N/A	N/A	N/A
<b>Total number of data publications</b>	24	37	34	63	37
Customers Accessing Data Publications	357	997	1,547	2,500	3,874
Percentage Increase in Customers Served	ND	179%	55%	61%	55%

1. Amendments extend existing CRADAs for additional years to a maximum of 5 years, and/or change Statements of Work, and/or change funding levels.
2. Material Transfer Research Agreements. Involves collaborative research on a specific material.
3. Includes mostly Trust Fund Cooperative Agreements, Reimbursable Agreements, Material Transfer Research Agreements, Specific Cooperative Agreements and Non-Funded Cooperative Agreements, Challenge Cost-Share Agreements, Collections Agreements, Cooperative Agreements, Inter-agency & Intra-agency Agreements, Joint Venture Agreements, Participating Agreements, Research Cost-Reimbursable Agreements, Research Joint Venture Agreements.
4. In 2014 the definition of this metric and the means of accounting for publications was changed and these factors can explain the large reduction in number of publication accomplishments for 2014 and beyond compared to FY2013 and earlier. This category is considered “Formally Refereed Publications” and is defined as “Documents, usually in journal or similar quality outlet, that are the result of material support from FS R&D, and on which the decision to publish is based on the results of a formal peer review and independent editorial decision.”

5. The definition for this metric changed in FY 2014 to “Informally Refereed Publications” and is defined as “scientific papers or similar documents that are the result of material support from R&D, and on which the decision to publish is made after peer reviews that are not independently commissioned (reviewers are selected by author or line officer). In past years, these publications may have been counted as journal publications, but from FY 2014 onward the new definition applies.
6. The Forest Service does not count Abstracts as accomplishments.

**TABLE 2. Invention Disclosure and Patenting**

\*ND-no data available.

Forest Service (FS)	FY 2012	FY 2013	FY2014	FY2015	FY2016
<b>Total number new invention disclosures<sup>1</sup></b>	23	24	13	24	20
University co-owned	ND	7	4	2	7
Based upon scientific discipline					
Life science	ND	3	4	6	8
Chemical	ND	8	4	6	2
Mechanical & measurement	ND	13	5	12	10
Plant patents		0	0	0	0
<b>Total number patent applications filed<sup>2</sup></b>	13	13	9	12	11
University co-owned	ND	9	6	7	6
Based upon scientific discipline					
Life science	ND	0	5	2	2
Chemical	ND	8	4	7	6
Mechanical & measurement	ND	5	0	3	3
Plant patents	ND	0	0	0	0
<b>Total number patents issued</b>	8	4	4	9	5
University co-owned	ND	1	1	4	4
Based upon scientific discipline					
Life science	ND	1	4	3	4
Chemical	ND	0	0	3	0
Mechanical & measurement	ND	3	0	3	1
Plant patents	ND	0	0	0	0

1. Inventions arising at the Federal lab.
2. Includes U.S. patent applications, foreign patent applications filed on cases for which no U.S. application was filed, divisional applications, continuation-in-part applications, and provisional applications.

**TABLE 3. Profile of Active Licenses**

\*ND-no data available.

Forest Service (FS)	FY 2012	FY 2013	FY2014	FY2015	FY2016
<b>Total number active licenses</b>	20	19	21	19	19
Executed to small businesses <sup>1</sup>	ND	1	3	2	2
Executed to startup businesses <sup>2</sup>	ND	2	1	1	1
Executed to universities	ND	14	17	16	16
<b>Invention licenses<sup>3</sup></b>	20	19	21	19	19
Executed to small businesses	ND	1	3	2	2
Executed to startup businesses	ND	2	1	1	1
Executed to universities	ND	14	17	16	16
<b>Other Intellectual Property Licenses<sup>4</sup></b>		0	0	0	0
Executed to small business	ND	0	0	0	0
Executed to startup businesses	ND	0	0	0	0
Executed to universities	ND	0	0	0	0
<b>Total number newly executed licenses</b>	3	2	2	0	2
Executed to small businesses	ND	0	0	0	0
Executed to startup businesses	ND	1	0	0	0
Executed to universities	ND	1	2	0	2
<b>Invention licenses</b>	20	19	21	19	19
Executed to small businesses	ND	1	3	2	2
Executed to startup businesses	ND	2	1	1	1
Executed to universities	ND	14	17	16	16
<b>Other Intellectual Property Licenses</b>	0	0	0	0	0
Executed to small businesses	ND	0	0	0	0
Executed to startup businesses	ND	0	0	0	0
Executed to universities	ND	0	0	0	0

1. A small business, together with its affiliates, must not have more than 500 employees.
2. For the purpose of this report, a startup company is a privately-held, U.S., for-profit company operating for less than 5 years and actively seeking financing to commercialize a Federal scientific work product.
3. Invention licenses refer to licenses resulting from a patent.
4. Other intellectual property licenses included biological materials licenses and plant variety protection licenses.

**TABLE 4. Characteristics of Income Bearing Licenses**

Forest Service (FS)	FY 2012	FY 2013	FY2014	FY2015	FY2016
<b>Total number of income bearing licenses</b>	18	18	21	19	19
Exclusive	17	17	20	18	18
Partially exclusive	0	0	0	0	0
Non-exclusive	1	1	1	1	1
<b>Invention licenses<sup>1</sup></b>	18	18	21	19	19
Exclusive	17	17	20	18	18
Partially exclusive	0	0	0	0	0
Non-exclusive	1	0	1	1	1
<b>Other Intellectual Property Licenses<sup>2</sup></b>	0	0	0	0	0
Exclusive	0	0	0	0	0
Partially exclusive	0	0	0	0	0
Non-exclusive	0	0	0	0	0
<b>Total number royalty bearing licenses</b>	18	18	21	19	19
Invention licenses	18	18	21	19	19
Material transfer licenses	0		0	0	0

1. Invention licenses refer to licenses resulting from a patent.

2. Other intellectual property licenses included biological materials licenses and plant variety protection licenses.

**TABLE 5. Income from Licensing**

\*ND-no data available.

Forest Service (FS)	FY 2012	FY 2013	FY2014	FY2015	FY2016
<b>Total income all active licenses</b>	\$12,733	\$3,763	\$2,230	\$2,878	\$2,634
Invention licenses	\$12,733	\$3,763	\$2,230	\$2,878	\$2,634
Biological materials licenses	0	0	0	0	0
<b>Total earned royalty income (ERI)</b>	\$658	\$1,763	\$230	\$878	\$634
Median ERI	\$329	\$340	\$230	\$439	\$317
Minimum ERI	\$312	\$256	\$230	\$256	\$11
Maximum ERI	\$346	\$827	\$230	\$623	\$623
ERI from top 1% of licenses	\$346	\$827	\$230	\$623	\$623
ERI from top 5% of licenses	\$346	\$827	\$230	\$623	\$623
ERI from top 20% of licenses	\$346	\$827	\$230	\$623	\$623
<b>Total income distributed</b>	\$0	\$10,788	\$2,230	\$2,878	\$2,634
Inventors	\$0	\$10,788	\$2,230	\$2,878	\$2,634
Salaries of some technology transfer staff	\$194,496	\$194,496	\$194,496	\$194,496	\$194,496
Patent filing preparation, fees, & annuity payments	\$46,445	\$15,144	\$15,600	\$13,500	\$63,053 <sup>4</sup>
Other technology transfer expenses (plaques)	\$926	\$665	\$910	\$1,158	\$320

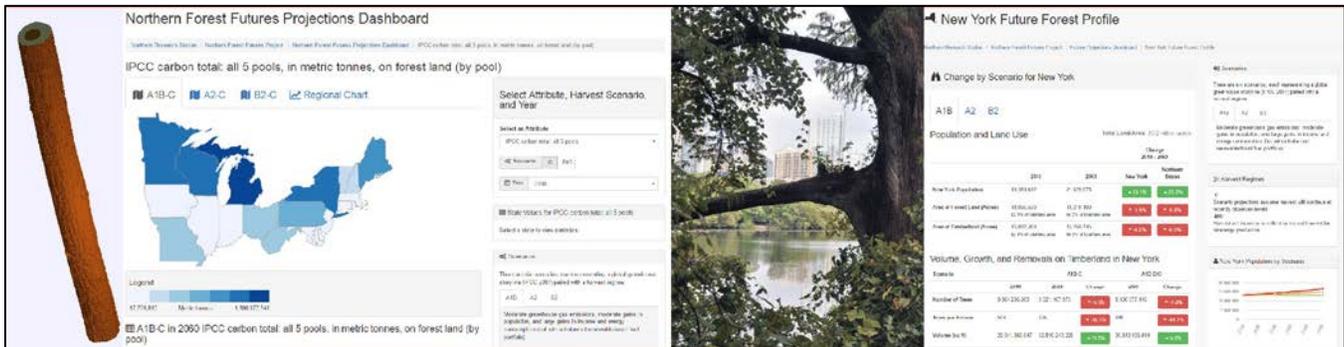
1. Not presented, represents one license.

2. Invention licenses refer to licenses resulting from a patent.

3. Other intellectual property licenses included biological materials licenses and plant variety protection licenses.

4. Outside attorney fees are included in FY 2016

## 6.6. Downstream Outcomes



## NORTHERN RESEARCH STATION

### New Technology Increases Value of Sawn Lumber

A set of prediction models based on correlations between external log defect indicators and internal defects for four hardwood species were released. Paired with a recently developed high-resolution laser log scanner that locates external log defects, the models help users estimate internal defect size, shape, depth, and position. The better than 90 percent accuracy of the models facilitates defect-free sawing – reducing waste and improving the value of lumber sawn.

*Northern Research Station, Newtown Square, Pennsylvania, Ed Thomas, 304-431-2324*

### Urban Forest Inventories Are Coming to a City Near You

In collaboration with State and local partners, the Forest Service’s Forest Inventory and Analysis Program (FIA) has begun monitoring urban forests, with special focus on the Nation’s largest cities. The first report, describing the urban forests of Austin, Texas, was released this year

(<https://doi.org/10.2737/NRS-RB-100>). The information presented can be used to improve and augment

support for urban forest management programs and to inform policy and planning to improve environmental quality and human health. <http://www.fs.fed.us/research/urban/fia.php>

*Northern Research Station, Newtown Square, Pennsylvania, Tonya Lister, 610-557-4033*

### **Managing the Future Forests of the Northern United States**

“Future Forests of the Northern United States” (<http://www.nrs.fs.fed.us/pubs/50448>), the latest report from the Northern Forest Futures Project, is a collaboration among the Station, Northeastern Area State and Private Forestry, and the Northeastern Area Association of State Foresters. It examines past trends, current conditions, and anticipated changes over the next 50 years for forests in the 20 Northern States bounded by Maine, Maryland, Missouri, and Minnesota. The publications, database, and interactive data dashboard help managers and policymakers examine 13 scenarios of forest change responding to land-use, economic trends, climate change, forest growth, forest harvest, and other factors.

Northern Forest Futures Projections Dashboard <http://www.nrs.fs.fed.us/futures/predict/>

Northern Forest Futures Project <http://www.nrs.fs.fed.us/futures/>

Northern Forest Futures Database <https://doi.org/10.2737/RDS-2015-0009>

*Northern Research Station, Newtown Square, Pennsylvania, Stephen Shifley, 537-875-5341*



## **PACIFIC NORTHWEST RESEARCH STATION**

### **State and Local Agencies Use Finding from Moss and Air Quality Study**

A study started by the Station in 2013 used moss collected from urban trees to develop fine-scale maps of air pollution in Portland, Oregon. In 2016, study findings contributed to new pollution controls, reexamination of the regulatory exemptions for the stained-glass industry, and the creation of a new State program called “Cleaner Air Oregon.” Urban moss analysis can revolutionize air quality monitoring by serving as an inexpensive screening tool to help cities quickly identify where to place pollution monitoring equipment.

### **Social Science Helps Public Map Places of Value, Informs Sustainable Road Strategy for Mt. Baker-Snoqualmie National Forest**

The Mt. Baker-Snoqualmie National Forest sought assistance from the Station to develop a public engagement process that used a systematic, socio-spatial approach for gathering information about public values, uses, and interactions that would inform the process of sustainable roads planning. End products were used by the forest’s interdisciplinary planning team when developing its 2016 Sustainable Roads Strategy Report. This “human ecology mapping” approach is also being used in the Deschutes

and Ochoco National Forests for pre-scoping in preparation for forest planning, and by the Bureau of Land Management in planning for the Browns Canyon National Monument in Colorado.

**Delivering smoke science tools to wildfire incident operations**

Station scientists supported Incident Command Teams deployed across the country by providing direct technical consultations and producing science-based tools and equipment aimed at serving the needs of fire management. This support included daily smoke model predictions that included very high resolution domains produced in partnership with the National Weather Service, as well as new tools for generating and archiving reports from air quality monitors near the fire, and improved web access to smoke monitor data.



## **PACIFIC SOUTHWEST RESEARCH STATION**

### **Statistical prediction helps land managers, firefighters get ahead of tree mortality**

California is experiencing dramatic tree mortality due to drought and bark beetles. The Station developed accurate forecasts of bark beetle location and intensity and resulting tree die-off 6 months earlier than standard aerial die-off surveys. California's Department of Forestry and Fire Protection has used the forecast as a warning system for increased fire risk, and Forest Service managers in the Pacific Southwest Region have used the forecast to identify areas in need of treatment to reduce fire risk.

*Pacific Southwest Research Station*, Haiganoush Preisler ([hpreisler@fs.fed.us](mailto:hpreisler@fs.fed.us))

### **A collaborative approach to prevent pathogen movement via restoration nursery stock**

*Phytophthora* and other plant pathogens are a problem for restoration activities; for example, the sudden oak death pathogen (*P. ramorum*), which has killed millions of oaks along the Pacific Coast, was introduced to California on ornamental nursery stock. The Station and representatives from >50 stakeholders formed the Working Group for Phytophthoras in Native Habitats ([www.calphytos.org](http://www.calphytos.org)) to

address this problem. The Working Group has developed management practices to minimize pathogen spread in restoration nurseries and the sites where nursery stock is later planted, and is coordinating research, monitoring, education, outreach and development of management and regulatory strategies to protect wildlands and assist native plant nurseries.

*Pacific Southwest Research Station*, Susan Frankel ([sfrankel@fs.fed.us](mailto:sfrankel@fs.fed.us))

### **Restoring productive California black oaks sustains cultural and ecological values**

Station scientists, along with a team of Federal researchers and tribal members, produced a [synthesis report](#) to guide restoration of degraded stands of California black oak. These acorn-bearing trees provide a treasured food for many Native Americans, as well as food and habitat for numerous wildlife species, but they are threatened by high-intensity wildfires and encroachment of shade-tolerant conifer species.

*Pacific Southwest Research Station*, Jonathan Long ([jwlong@fs.fed.us](mailto:jwlong@fs.fed.us)) and Frank Lake ([franklake@fs.fed.us](mailto:franklake@fs.fed.us))



## ROCKY MOUNTAIN RESEARCH STATION

### Keeping Waterways Clean

Developed (with partners) [analytic tools](#) that identify specific areas where water drains off forest roads and carries unwanted sediment into waterways. These tools, [GRAIP](#) (Geomorphic Road Analysis and Inventory Package) and GRAIP-Lite, informed new [Environmental Protection Agency policy decisions](#) and are regularly used by land managers to decide where to implement projects.

### Protecting Bridge Infrastructure

Secured a patent for a method to measure variations in the elevation of a streambed over time, which is of practical importance for measuring bed scour around bridge piers. Engineers can use this to monitor how much scour is occurring around bridge piers. The sensors being developed to complement the method are very inexpensive compared to sending divers down to inspect periodically. This will help prevent unexpected bridge collapses by providing real-time continuous scour monitoring at piers.

## **Sagebrush Decision Support**

[“Using Resilience and Resistance Concepts to Manage Threats to Sagebrush Ecosystems, Gunnison Sage-Grouse, and Greater Sage-Grouse in Their Eastern Range: A Strategic Multi-Scale Approach”](#)

provides a new decision-support process for land managers to help them ensure that effective actions are implemented in the right places, consistently through time, to restore and maintain functioning sagebrush ecosystems and to conserve Gunnison sage-grouse and Greater sage-grouse.

## **Diagnosing Tree Diseases**

[“Diseases of Trees in the Great Plains”](#) identifies tree hosts, tree distribution, disease symptoms and signs, disease cycles, and management strategies for 84 hardwood and 32 conifer diseases found in the Great Plains. The publication includes color illustrations, a glossary of technical terms, and indexes of hosts and pathogens. It covers diseases of foliage, roots, stems, and branches; soil-borne and wilt diseases; and the safe handling and use of pesticides. This book is helping users (e.g., arborists, landowners, pest management specialists, foresters, pathologists) diagnose and reduce the economic and esthetic impact of these diseases.



## SOUTHERN RESEARCH STATION

### Why Fire Is Good (But You Still Shouldn't Start a Forest Fire)

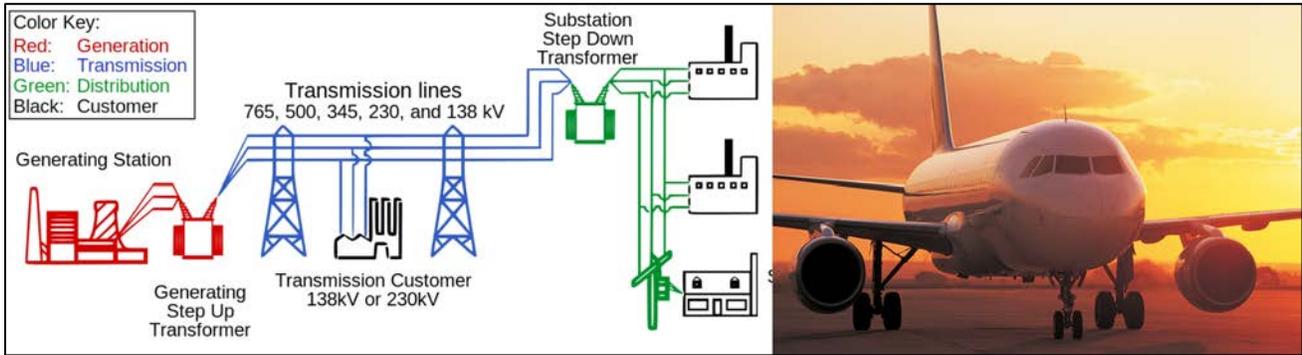
U.S. forests need fire to help foster diversity and new growth. The Station partnered with [Untamed Science](#) to create an educational video that highlights research that delves into the history of the use of fire and how fire benefits forests. The video is being used by schools, universities, conservation organizations, and other government agencies to help educate the public on how fire can be used effectively to help the forest. Link: [Why Fire is Good \(But You Still Shouldn't Start a Forest Fire\)](#)

### TACCIMO Supports First Draft Forest Plan under New Planning Rule

Working with the Station's Eastern Forest Environmental Threat Assessment Center's web-based [Template for Assessing Climate Change Impacts and Management Options \(TACCIMO\)](#), the Francis Marion National Forest planning team was able to access the best available science during the development of its Forest Plan. The team was able to use TACCIMO to gain additional insight into the key characteristics of climate change affecting specific resources. Forest planners also used TACCIMO to develop a monitoring plan which provides the information needed to respond to changing conditions, including climate change.

## **Story Maps Bringing Information to Life**

The Station's Forest Inventory and Analysis (FIA) unit is increasing the interactivity and reach of forest science by using FIA and other data to create story maps. Developed on Esri's ArcGIS Online platform, story maps are stand-alone web-based resources that combines maps, text, videos and photos. [Southern Forest Products – An Economic Engine](#) allows viewers to interactively chart the ebb and flow of forest products across the southern states. [Fighting the Battle for the Bats](#) provides a guide to the spread of white-nose syndrome. The platform is also being used for FIA annual reports – see [FIA StoryMaps](#).



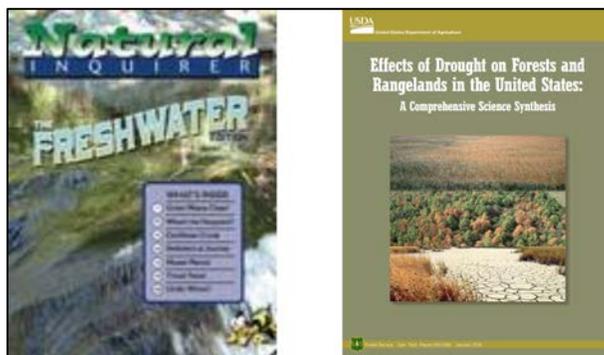
## **FOREST PRODUCTS LABORATORY**

### **Electricity generation innovation**

The Laboratory has partnered with Tucker Engineering Associates to compare the life-cycle impacts associated with generating electricity from synthetic gas produced from a new distributed-scale thermochemical conversion system using whole-tree wood chips as feedstock to coal and natural gas electricity.

### **Wood hydrolysis and fermentation for jet fuel**

The Laboratory has participated in the USDA regional biomass project titled the Northwest Area Renewables Alliance (NARA) led by Washington State University. NARA selected the Lab's patented sulfite pretreatment process (SPORL) biomass pretreatment process to treat 60 tons of Douglas fir forest residuals to produce jet fuel. The SPORL pretreatment was completed in August and further biomass processing continues.



## WASHINGTON OFFICE

### Science Education Journals

The *Natural Inquirer* program creates and distributes re-usable science journals written for K-12 students. In FY 2016, 67,440 of these products were distributed to classrooms and homeschools across the country. Our web site had 72,834 visitors in FY 2016, a 25-percent increase over FY 2015. All work is done with our non-profit partner, the Cradle of Forestry in America Interpretive Association, and the University of Georgia. <http://naturalinquirer.org>

*WO R&D KMC, Barbara McDonald, Ph.D., Education Program Manager, 706-559-4224*

### Effects of Drought

Coverage of our report [Effects of Drought on Forests and Rangelands in the United States: A Comprehensive Science Synthesis](#) in many major media outlets—including the [San Francisco Chronicle](#), [Christian Science Monitor](#), and [Scientific American](#)—helped educate the public, scientists, and others on Forest Service research on drought. An accompanying [webinar](#) was watched by approximately 300

scientists, land managers, academics and foresters; about 85 percent of surveyed webinar attendees expressed a likelihood of adopting information or techniques presented in the webinar.



FSIS applies the latest technologies to assure the safety of meat, poultry, catfish and egg products.



FSIS employs a variety of techniques to communicate safe food handling practices to consumers.



FSIS activities lead to safer food for consumers.

## 7.0. USDA Food Safety and Inspection Program

<http://www.fsis.usda.gov>

### 7.1. Mission Statement

The Food Safety and Inspection Service (FSIS) is the public health agency in the U.S. Department of Agriculture responsible for ensuring that the Nation's commercial supply of meat, poultry, catfish, and egg products is safe, wholesome, and correctly labeled and packaged.

### 7.2. Nature and Structure of the Program

FSIS applies the latest advances in food safety technologies to reduce foodborne diseases and monitors chemical and microbial hazards in meat, poultry, and egg products. FSIS also facilitates the application of food safety technologies to food production. In addition, the agency conducts outreach to consumers with food safety messages throughout the year.

The FSIS Research Priorities Review Panel routinely identifies and prioritizes research that assists the agency in its mission to protect public health. The list of current FSIS research priorities include:

- Developing analytical methods to increase the efficiency of laboratory analyses
- Identifying and understanding emerging chemical and microbial hazards
- Identifying and evaluating hazard mitigation techniques (e.g., pathogen interventions for food processing establishments)
- Improving the transfer of food safety knowledge to consumers.

Although FSIS is not a research agency, FSIS addresses its scientific information and data needs through partnerships with a variety of Federal agencies, universities, and industry. The agency prioritizes and communicates its needs to our partners and stakeholders during meetings with agency leadership and scientists, seminars at universities and scientific conferences, and postings on the FSIS website. In FY 2016, the FSIS Research Priorities page on the FSIS website was accessed on more than 7,000 occasions a 75-percent increase versus FY 2015. Moreover, about 50 percent of users navigated to associated pages for additional information on the FSIS Research Priorities and associated studies. About 50 percent of page views were by new visitors and 50 percent were return visitors. About 50 percent of visitors are referred by search engines or partner agency websites. During FY 2016, FSIS added one new research priority (Determine the contribution of endogenous extra-intestinal sources of pathogens to contamination of FSIS-regulated products) and four new priority associated study suggestions.

### 7.3. Activities in FY2016

#### **Adoption of Whole Genome Sequencing for the Routine Characterization of Pathogens**

Whole Genome Sequencing (WGS) is a rapidly evolving and powerful characterization technology that can provide an indepth discrimination between closely related bacterial isolates. In FY 2016, FSIS deployed 3 additional WGS instruments and has a total of seven sequencers. One of these instruments was procured for the Midwestern Laboratory, thereby increasing the capability within the FSIS laboratory system. The procurement of additional sequencers increased the agency's capacity for "real-time" sequencing of pathogen isolates. To further strengthen FSIS' WGS capability and to develop a shared understanding among Federal public health partners on the rapidly evolving WGS issues, FSIS continues to engage with the Centers for Disease Control and Prevention, the U.S. Food and Drug Administration, and the National Center for Biotechnology Information /Institutes of Health via a formalized collaboration called Gen-FS. FSIS continued to provide expertise on Gen-FS workgroups dealing with communication, analytical standardization, and harmonization between Federal partners.

As WGS is fully implemented in FSIS, the agency plans to use this technology and the data to assist establishments in developing effective Hazard Analysis Critical Control Point (HACCP) systems for taking effective corrective actions and for performing adequate reassessments. The WGS data will also be used by FSIS to explore/identify environmental harborage and recurrences of pathogens in FSIS-regulated establishments. In support of WGS adoption during FY 2016, FSIS performed WGS on all adulterant isolates, National Antimicrobial Resistance Monitoring System (NARMS) cecal *Salmonella* and *Campylobacter* samples, and isolates involved in outbreak investigations. Each of these sequencing

initiatives supported public health initiatives such as outbreak investigations and partnerships within the NARMS.

### **Adoption of New Carcass Rinse Solution**

Antimicrobial chemical solutions (interventions) are applied to poultry carcasses during processing. These antimicrobial interventions increase product safety by reducing pathogens on poultry. Research has shown that some interventions have the potential to carry-over to poultry sampling solutions and to impact *Salmonella* analyses. To mitigate this potential carry-over impact, the USDA Agricultural Research Service developed a neutralizing buffered peptone water (nBPW) carcass rinse solution that incorporates neutralizing agents to reduce the potential impact of intervention carry-over on *Salmonella* analyses.

FSIS has no evidence to suggest that intervention carry-over impacted the Agency's pathogen sampling results. To reduce the future potential of such intervention carry-over impact on sampling results, FSIS proactively adopted nBPW for poultry sampling. On July 1, 2016, FSIS began using nBPW for domestic and imported poultry verification sampling, including chicken carcass rinses, poultry parts rinses, and young turkey carcass sponge swabs.

### **Adoption of New Technologies To Facilitate Information Transfer to FSIS Inspectors and**

#### **Industry**

FSIS expanded its reach into ever more sophisticated technologies as new platforms for training. FSIS is developing 3-D, virtual reality video segments to support instruction for food safety inspectors and

orient potential job applicants to authentic slaughterhouse operations. Users watch live action videos – shot at establishments in operation – using virtual reality goggles. Just by turning their heads, viewers can experience a 360-degree view. To capture meat and poultry processing scenes, FSIS used video recording equipment similar to the mobile Google Maps camera and is now editing the footage into learner-activated, instructional vignettes. These scenes give users the next-best experience to being in a processing plant and assist them in learning their job tasks in an authentic manner.

FSIS also introduced an online IPP (Inspection Program Personnel) Help feature, available via a desktop icon. The icon opens a menu of training topics pertaining to IPP job tasks, for example, fundamentals of HACCP verification; how to package samples for lab analysis, featuring large, color photos; and how to use the Public Health Information System (PHIS) database, including live-screen demonstrations and interactive simulations. The online IPP Help feature is updated regularly throughout the year as IPP needs arise. Since the IPP Help site’s launch in FY 2016, it has received an average of 20,000 “hits” (electronic visits) each month.

### **Facilitating the Application of New Food Safety Technologies to Food Production**

FSIS encourages continued improvement and innovation in food safety technologies. During FY 2016, FSIS evaluated new technologies aimed at enhancing food safety, including new commercial pathogen interventions, process innovations, and new ingredient usages proposed by industry. If the evaluation indicates that the agency has no safety concerns with the proposal, the agency issues a “no objection” letter, which facilitates the adoption of new technologies for production of FSIS-regulated products. In FY 2016, FSIS evaluated 127 new technology submissions. Of these submissions, FSIS issued 60 “no

objection” letters. These no objection letters facilitate the adoption of food ingredients to enhance the safety of FSIS regulated products

### **Facilitating the Application of Food Safety Research Findings To Produce Safe Food and Compliance With FSIS Guidance and Regulations**

In FY 2016, FSIS released seven guidance documents to assist industry with identifying and applying relevant scientific findings to produce safe meat, poultry, and egg products, including:

- FSIS Compliance Guidance for Label Approval (November 2015) FSIS published this compliance guidance to provide information about the types of labels and labeling that need to be submitted to the agency for approval.
- DRAFT Compliance Guideline for Controlling *Salmonella* and *Campylobacter* in Raw Poultry Fourth Edition (December 2015) This document provides industry guidance on how to control *Salmonella* and *Campylobacter*.
- FSIS Compliance Guideline for the Prevention and Control of *Trichinella* and Other Parasitic Hazards in Pork and Products Containing Pork (March 2016). This guideline provides information on the prevention and control of *Trichinella spiralis* and other parasitic hazards in products containing pork.
- Food Safety Equivalence and Inspection Seminar. FSIS hosted a webinar on September 13, 2016, about the Self-Reporting Tool and the Public Health Information System.

- Allergen Management, Labeling, and Economics of Related Recalls for FSIS-Regulated Products: FSIS hosted a webinar on June 7, 2016, to discuss the updated FSIS guidance document “FSIS Compliance Guideline: Allergens and Ingredients of Public Health Concern: Identification, Prevention and Control, and Declaration Through Labeling.”

### **FSIS Uses Science-Based Food Safety Information To Educate Consumers and Other Stakeholders**

FSIS plans, coordinates, conducts, and updates consumer food safety education campaigns and related outreach activities. FSIS originated and continues to promote the Food Safe Families campaign, an advertising, partnerships, public relations, digital and social media campaign based on the latest food safety research with consumers. FSIS used the results of the International Food Information Council’s Food and Health Survey and an observational study conducted by Kansas State University to formulate messaging and establish communications priorities for this campaign.

FSIS collaborates with the Centers for Disease Control and Prevention, the Food and Drug Administration, and the Ad Council to develop Public Service Announcements (PSAs) for the advertising portion of this campaign, which wrapped up in 2016. The *Food Safe Families* campaign features PSAs that promote four safe food handling behaviors to consumers: *Clean/Separate/Cook/Chill*.

The PSAs inform consumers about simple steps to protect their families from foodborne illness. During FY 2016, the *Food Safe Families* Campaign received more than \$17,249,901 in complimentary advertising from the Ad Council, achieved 520,261 detections and 339,572,000 impressions.

Cumulatively, this Ad Council contract has generated more than \$144 million in donated media, 3,734,166 detections, and more than 9 billion impressions since its launch in June 2011. PSAs created in partnership with the Ad Council and 20th Century Fox using the characters from Alvin and the Chipmunks were launched in early October 2015. The partnership included PSAs on billboards, bus shelters, and television channels across the Nation. A multimedia news release promoting the partnership appeared on 238 websites with a potential audience of 170,888,532. The Ad Council page for the release of this information was viewed 13,150 times and children's activity pages launched on FoodSafety.gov promoting the partnership were viewed 20,688 times.

This fiscal year, FSIS also developed a teacher-to-parent activation kit in coordination with the Ad Council and Scholastic using the "Alvin and the Chipmunks" characters and FSIS' mascot "Thermy." These educational materials included a lesson plan for teachers to conduct with 2nd through 4th grade students, and take-home materials for students to review with parents after their lesson. The materials were available digitally this spring and were sent physically to teachers in the fall. The impact of the in-school marketing program with Scholastic is not represented in traditional reporting; however, nearly 400,000 food safety themed emails were sent to parents and teachers, which delivered over 500,000 banner impressions and received 1.2 million content integration impressions from Scholastic's homepage, Facebook page, and e-newsletters. In addition, 50,000 bundled family magazines were delivered via school classrooms this fall, with an estimated reach of 1.5 million families and 50,000 teachers.

Key components of FSIS' consumer education program include the USDA Meat and Poultry Hotline, the USDA Food Safety Discovery Zone traveling exhibit, and the FSIS web-based virtual representative initiative "Ask Karen." The USDA Meat and Poultry Hotline operated throughout the year, including the

hotline's busiest time of year, the November–December holiday season. The Hotline operated from 8:00 am until 2:00 pm on Thanksgiving Day answering consumer food safety questions, which focused on turkey preparation, storage, and handling. The Hotline responded to nearly 68,350 inquiries (calls, webmail, and chats) in 2016. The “Ask Karen” database received 11,116 email questions, and 2,389,921 answers were viewed. During FY 2016, the USDA Food Safety Discovery Zone attended 22 outreach events in 11 States, and achieved approximately 1.5 million consumer impressions of its food safety messages. In 2016, FSIS also launched the “Ask Small Plant Help Desk” web-based virtual representative. Modeled after “Ask Karen,” the “Ask Small Plant Help Desk” is a resource for small and very small producers for FSIS information.

The completion and launch of the FoodKeeper cell phone application (app) in April 2015 was a significant accomplishment. This app was developed by FSIS, Cornell University, and the Food Marketing Institute and offers users valuable storage advice for more than 400 food and beverage items, including various types of baby food, dairy products, and eggs, meat, poultry, produce, seafood, and more. The FoodKeeper app remains a relevant, useful and effective way to educate consumers about proper food storage and its relationship to safe food-handling behaviors. In FY 2016, an additional 40,000 users downloaded the application, bringing its total installs to nearly 150,000. The app was mentioned in the Washington Post, and the USA.gov blog called it “one of the government’s best mobile applications.” The application provides consumers with information about safe handling and storage times for hundreds of food items, thereby supporting the Secretary’s goal to reduce food waste. The app is available for Android smartphones and tablets, and iOS products.

With the app users can:

- Find storage timelines for refrigerator-, freezer-, and pantry-stored products;
- Get tips for cooking methods of meat, poultry and seafood products;
- Note in the device's calendar when products were purchased and receive notifications when they are nearing the end of their recommended storage date;
- Submit a question to USDA using the "Ask Karen" feature of the app. "Ask Karen" is USDA's 24/7 virtual representative. The system provides information about preventing foodborne illness, safe food-handling and storage, and safe preparation of meat, poultry, and egg products.

The following features were made public when version 5.0 of the application was released in June 2016:

- Multi-lingual support – Provides Spanish and Portuguese versions of the app. Allows users to set app to display in English, Spanish, or Portuguese as well as switch language through App Settings or Device Settings menu.
- Display measurements – Supports Metric and Imperial formats (°C or °F).
- Calendar – Improves existing event calendar capabilities.

Social media also is an integral part of the agency's educational outreach. During FY 2016, FSIS used a variety of social media networks to promote recalls and communicate about proper safe food-handling practices. FSIS used Twitter, Facebook, YouTube, blogs, and webinars for routine outreach. FSIS used

pop culture topics like Ghostbusters, #PokémonGo, and the 2016 Rio Olympics to promote food safety messages to audiences engaged in discussion about those trending topics.

The @[USDAFoodSafety](#) Twitter account and the FoodSafety.gov Facebook account continued to see growth throughout the year due to the ongoing strategy of using non-traditional topics to communicate food safety messages. Twitter engagements saw a 15-percent increase from last year, meeting this year's goal, and Facebook engagements increased by 10 percent. FSIS has seen considerable success in Twitter followers, reaching a new total of 787,072 followers. FSIS surpassed the target of 780,000 set for FY 2016. FSIS' most successful campaigns include #GrillingLikeaPRO with 360,002 impressions, Thanksgiving Food Safety with 1.1 million impressions, and Super Bowl Food Safety with 378,559 impressions.

In FY 2016, FSIS has continued to see high engagement with traditional food safety messages accompanied by infographics. For example, FSIS shared the *Food Safety Before, During and After a Power Outage* infographic for severe weather multiple times on FSIS social media platforms, generating more than 1.6 million impressions on Twitter.

### **Transferring Analytical Methods Development Research and New Technologies to FSIS**

#### **Laboratories for Monitoring Hazards in Meat, Poultry, Catfish, and Processed Egg Products**

FSIS laboratories deploy new technologies to better monitor hazards in meat, poultry, and egg products and to minimize human exposure to foodborne hazards. In FY 2016, FSIS validated and adopted 16 new or revised laboratory methods. These methods improve the agency's ability to monitor potentially

hazardous concentrations of chemicals (e.g., antibiotics, pesticides, environmental contaminants, and growth promoters) and microbial pathogens in food. These new FSIS methods include:

- Multi-residue methods to detect veterinary drug and pesticides to assure that FSIS-regulated products do not contain unsafe levels of chemicals. The new methods were developed by the USDA Agricultural Research Service and validated and implemented in FSIS laboratories. These methods are suitable for screening a variety of pesticides and drugs in bovine, caprine, equine, ovine, porcine, poultry, and catfish tissue. Results from these methods are used both for regulatory enforcement purposes and for FSIS, U.S. Food and Drug Administration and U.S. Environmental Protection Agency consumer chemical exposure and risk assessments.
- A chemistry method to quantify metals to assure that beef, pork, poultry, and catfish do not contain unsafe levels of Lead, Cadmium, Selenium, Manganese, Molybdenum, Thallium, Cobalt, Iron, Zinc, Copper, Nickel, Aluminum, Boron, Barium, Chromium, Vanadium, and/or Strontium. This method is suitable for the quantification of metals (typically environmental contaminants) in food animals and is used by the Agency to assure that the concentrations of metals in foods do not present a public health concern to consumers.
- A chemistry method to assess beta-agonists in bovine, porcine, and equine tissues to assure that the levels of clenbuterol, salbutamol, cimaterol, zilpaterol, and ractopamine do not present a public health concern to consumers. Beta-agonists are used for growth promotion in food animals.

- A chemistry method for speciation of catfish. This method permits FSIS to prevent fraudulent mislabeling of catfish products and to minimize the risk of potential health hazards associated with some specific species.
- Molecular detection method that increases the number of *Salmonella* serotypes that can be monitored by FSIS. This enables FSIS to better monitor *Salmonella* on meat, poultry, egg products, and catfish.
- Polymerase Chain Reaction and microbiology-based methods to monitor *Campylobacter* on poultry products permit FSIS to reduce the probability of food-borne illness to consumers.

## **8.0. Grain Inspection, Packers and Stockyards Administration (GIPSA)**

<http://www.gipsa.usda.gov/>

### **8.1. Mission Statement**

To facilitate the marketing of livestock, poultry, meat, cereals, oilseeds, and related agricultural products, and promote fair and competitive trading practices for the overall benefit of consumers and American agriculture.

### **8.2. Strategic Plan**

GIPSA's Strategic Plan serves to ensure fair and transparent markets free from deceptive and fraudulent practices, combined with recognized and reliable descriptors of crop quality and value, to promote economic health and prosperity in American agriculture. U.S. farmers produce a wide variety of agricultural products, and the vast American infrastructure permits these products to be processed and distributed throughout the United States and international markets effectively and efficiently. The markets serviced by GIPSA represent a total economic value of approximately \$170 billion annually, with exports contributing over \$28.7 billion to the U.S. economy.

### **8.3. Nature and Structure of Research Programs**

GIPSA maintains a strong presence, domestically and internationally, in the development, evaluation, and implementation of practical grain quality assessment and inspection methods. Our laboratories work with the latest technologies, and through these technologies and our ongoing efforts, we are helping to

improve the quality of U.S. grain available to the global market. To enhance marketing of grain into the future, we are also conducting internal research and participating in development and collaborative efforts with other governmental entities, laboratories, and private business. The research and analysis we conduct is in response to clear and widespread market needs. In general, GIPSA research is highly “applied,” in that GIPSA’s successful projects result in direct and immediate use by the U.S. grain industry. GIPSA also develops written information for customers and stakeholders, including scientific publications, publications in trade journals, and reports to stakeholders.

As agricultural crops evolve and varieties with enhanced traits are developed, reliable tests must be developed to detect and quantify the quality traits important to the market. GIPSA conducts a research program to assess the performance of rapid test kits that are designed for detecting and/or quantifying the presence of mycotoxins in grain or for detecting the presence of specific biotechnology-derived traits in grain to allow test kit manufacturers to make verified claims regarding their products. GIPSA research results in new applications of existing technologies, such as near-infrared spectroscopy and nuclear magnetic resonance, and improvements in those technologies to meet identified market needs for grain quality assessments.

#### **8.4. Current Technology Transfer Goals, Objectives, and Measures of Success (Metrics)**

##### **8.4.1. Current Technology Transfer Initiatives**

Visually identifying quality factors within grain and other commodities requires clear light that appropriately illuminates the product being graded. GIPSA has identified a need for light emitting diode (LED) lights as an alternative to fluorescent lights currently required for use within the official

inspection system. GIPSA is working to identify the specifications for LED lights that equate to the requirements established for grading and is currently working with a manufacturer who may be able to provide a commercial product that meets these specifications.

Using technology that can provide an objective measurement of quality factors currently measured by visual assessment can result in increased consistency between measurements. Reducing the amount of time required to complete the assessment adds additional value to the measurement process. GIPSA is exploring how use of imaging and near-infrared technology can be effectively integrated into the Official grain inspection system.

GIPSA continues to work with manufacturers of rapid test kits used to detect mycotoxins and approved genetic events in grain to certify the test kits. GIPSA also approves the use of mycotoxin test kits for use within the official inspection system. GIPSA provides a monthly update of all approved rapid test kits on its public website. GIPSA has approved 39 rapid test kits for detection of aflatoxin, deoxynivalenol, and fumonisin. GIPSA has approved 11 rapid test kits for detection of specific approved genetic events in corn, soybeans, and maize.

#### **8.4.2. CRADA Activities**

GIPSA has a CRADA with QualySense AG to assess how the use of imaging a near-infrared technology can be effectively integrated into the Official grain inspection system. GIPSA's Technology and Science Division (TSD) and QualySense AG have entered into a Cooperative Research and Development Agreement (CRADA) to collaborate on research and development of innovative technologies for accurate, consistent, and efficient assessment of grain quality. QualySense is a Swiss-

based company providing equipment for high-speed inspection and sorting of grains, seeds, and beans by biochemical and/or geometrical properties. The purpose of the collaboration is to support scientific advances in testing and measurement of grain quality by means of high-speed kernel imaging and near-infrared technologies (NIR). The collaboration is research oriented and is intended to:

- Evaluate the imaging and NIR technologies for potential applications in grain inspection;
- Explore the development of novel inspection standards using high-speed, single-kernel imaging and NIR technologies for measuring one or more quality traits that can be used to characterize the biological and commercial value of a commodity;
- Identify and resolve limitations, issues, and concerns with the technologies to improve their performance and suitability; and
- Identify and address issues, and concerns related to specific crop and/or applications, sampling processes, inspection procedures, and other factors that may impact the accuracy, consistency, or efficiency of grain quality assessments.

The research focus for the 1st year will be potential applications to rice inspection and to wheat inspection. Other commodities and applications may be assessed in subsequent years. The CRADA protects proprietary or confidential information brought to the effort by QvalySense. Information arising from the CRADA that is owned or co-owned by the U.S. Government may be made available to others by GIPSA for bona fide research or commercial purposes provided (1) confidentiality is not breached and (2) patent or copyright rights are not compromised. This CRADA is not an evaluation of

the QalySense instruments and technology for adoption in the official grain inspection system.

### 8.4.3. Measures of Success

GIPSA measures its success in terms of the percentage of market needs, which are grain and commodity quality factors, which are addressed through the official inspection system. GIPSA currently provides tests that address 98 percent of current market needs as identified by the grain exporting industry.

GIPSA is in the process of reviewing all market needs in order to ensure that emerging quality factors critical to marketing grain are addressed. Another metric used is the number of quality and weight complaints we receive from our customers each fiscal year. GIPSA has received no complaints that indicate any issue with the method used to assess any quality factors during FY 2016.

### 8.5. Downstream Outcomes

- **Harmonizing Biotech Reference Methods.** There is a need for highly specific and accurate tests for the various genetically engineered (GE) crops grown in the United States. GIPSA has developed intra-laboratory-validated, real-time polymerase chain reaction (PCR) methods and has evaluated the accuracy, reliability, and proficiency of publicly available methods used to detect and identify GE grains and oilseeds. GIPSA participated on a scientific panel of experts engaging U.S. stakeholders and influencing outcomes on issues related to testing of GE traits in grains with the goal of developing global scientific consensus regarding the analysis of transgenic events.

- Through the USDA/GIPSA Corn and Soy Proficiency Program, USDA seeks to improve the overall performance of testing for biotechnology-derived grains and oil seeds. The USDA/GIPSA proficiency program report contains inter-laboratory comparisons for the purpose of proficiency testing (i.e., to determine the performance of individual laboratories' ability to detect and/or quantify transgenic traits in corn or soy as well as to monitor laboratories' continuing performance). The program does not assess the effectiveness of different detection methods for biotechnology-derived traits, nor does it determine the characteristics of fortified samples to a particular degree of accuracy. However, the USDA/GIPSA Proficiency Program helps organizations identify areas of concern and take corrective actions to improve testing precision, capability, and reliability.
- GIPSA continues to collaborate with international organizations such as Codex Alimentarius, International Organization for Standardization, American Association of Cereal Chemists, American Oil Chemists' Society, Institute for Reference Materials and Measurements, and the Canadian Grain Commission to harmonize testing technologies for GE grains and oilseeds.
- **Export Wheat, Soybean and Corn Quality Surveys.** GIPSA coordinates with representatives of U.S. Wheat Associates and the U.S. Grains Council to conduct export wheat, soybean, and corn surveys. GIPSA assisted with the wheat survey by collecting samples, providing inspection results, and performing additional tests for pesticide residues and heavy metals. GIPSA has assisted with the wheat survey for over 30 years and has been conducting corn and soybean surveys periodically since 2012. The two market development organizations use the data to advise importers worldwide on what is available for sale, the cost, and the advantages that U.S. wheat, soybeans, and corn have over the competition.

## **8.6. Outreach Activities**

### **8.6.1. Domestic Outreach**

- GIPSA reviewed work underway with the CRADA with QualySense AG with the Industry Standards Committee of USA Rice Association at its annual conference in New Orleans, LA.

### **8.6.2. International Outreach**

- A GIPSA scientist attended the International Food Safety Training Laboratory, which is a part of the Joint Institute for Food Safety and Applied Nutrition (JIFSAN). JIFSAN is a joint collaboration between the U.S. Food and Drug Administration and the University of Maryland and helps provide the scientific basis for ensuring a safe, wholesome food supply as well as provide the infrastructure for contributions to food safety programs and international food standards. The purpose of the training was to educate international scientists involved in food safety on mycotoxin testing methods in food.
- A GIPSA scientist served as a member (alternate delegate) of the U.S. delegation to the Codex Committee on Methods of Analysis and Sampling meeting held in Budapest, Hungary. The U.S. delegation actively participates in continuing discussions on uncertainty of sampling, conformity assessment, and processes for resolution of disputes.
- In FY 2016, GIPSA responded to customers' needs for technical assistance in foreign markets. Exporters, importers, and end-users of U.S. grains and oilseeds, as well as other USDA agencies,

USDA cooperator organizations, and other governments ask for GIPSA expertise. GIPSA provides grain-marketing and grain-grading seminars, meets with foreign governments and grain industry representatives to resolve grain-quality and weight discrepancies, helps other countries develop domestic grain and commodity standards and marketing infrastructures, assists importers with quality specifications, and trains local inspectors in U.S. inspection methods and procedures. In FY 2016, GIPSA's senior grain-grading representative, the Chairman of the Board of Appeals and Review, spent 30 days in southeast Asia presenting onsite seminars with foreign grain buyers and end users, explaining both objective and visually based grain quality measurement processes, instruments, and equipment used by GIPSA. Such activities are funded through various programs administered by the Foreign Agricultural Service (FAS) or directly by GIPSA. Outreach activities serve to strengthen the U.S. reputation for being a reliable supplier of high-quality grain, to reinforce the integrity of GIPSA as an independent quality inspection authority, and to minimize discrepancies in inspection results between GIPSA and the importer.

- GIPSA personnel frequently meet with delegations visiting from other countries to brief them on the U.S. grain marketing system, our national inspection and weighing system, U.S. grain standards, and our mission. Many of these delegations are sponsored by USDA Cooperator organizations like U.S. Wheat Associates and U.S. Grains Council, which arrange visits to grain production areas, GIPSA field offices, onsite laboratories at export grain elevators, and our National Grain Center in Kansas City, Missouri. At the National Grain Center, delegations sometimes receive technical training on analytical testing procedures and grain inspection methods and procedures.

- Briefings are tailored to address each group's interests and concerns. Presentations include explanations of the various services available from GIPSA, our use of the latest technology to provide grain traders with accurate and reliable inspection and weighing information, and for importers or potential importers new to the U.S. grain market, information on contracting for the quality they desire. These briefings foster a better understanding of the entire U.S. grain marketing system and serve to enhance purchasers' confidence in U.S. grain. Ultimately, these efforts help move our Nation's harvest to end-users around the globe. During 2016, GIPSA personnel met with 32 teams from 21 countries.

## **8.7. Publications**

### **8.7.1. Internet Publications**

- The GIPSA Performance Verified Mycotoxin Rapid Test Kits matrix is located on GIPSA's website at:  
[https://www.gipsa.usda.gov/fgis/metheqp/GIPSA\\_Approved\\_Mycotoxin\\_Rapid\\_Test\\_Kits.pdf](https://www.gipsa.usda.gov/fgis/metheqp/GIPSA_Approved_Mycotoxin_Rapid_Test_Kits.pdf).  
The matrix is updated on a monthly basis.
- The GIPSA Performance Verified Biotech Rapid Test Kits matrix is located on GIPSA's website at: [https://gipsa.usda.gov/fgis/metheqp/GIPSA\\_Approved\\_Biotech\\_Rapid\\_TestKits.pdf](https://gipsa.usda.gov/fgis/metheqp/GIPSA_Approved_Biotech_Rapid_TestKits.pdf). The matrix is updated as new tests are approved.
- The GIPSA Biotechnology Proficiency Report is located on GIPSA's website at:

[https://www.gipsa.usda.gov/fgis/biotech/quarterly\\_reports/April\\_2016\\_Proficiency\\_Report\\_Final.pdf](https://www.gipsa.usda.gov/fgis/biotech/quarterly_reports/April_2016_Proficiency_Report_Final.pdf)

## **9. National Agricultural Statistics Service (NASS)**

<http://www.nass.usda.gov/>

### **9.1. Mission Statement**

“The National Agricultural Statistics Service provides timely, accurate, and useful statistics in service to U.S. agriculture.” The statistics NASS compiles are used by agricultural producers and businesses to ensure an orderly flow of goods and services among agriculture’s production, processing, and marketing sectors. Reliable, timely, and detailed crop and livestock statistics help to maintain a stable economic climate and minimize the uncertainties and risks associated with the production, marketing, and distribution of commodities.

NASS data are also vital to policymakers, researchers, and scientists in the agriculture community who depend on reliable and unbiased facts. The Census of Agriculture, conducted every 5 years, provides comprehensive, county-level data about agricultural communities across the United States. NASS statistical data are essential to both the public and the private sector for making effective policy and for production and marketing decisions.

### **9.2. Nature and Structure of Research Program**

NASS primarily conducts applied research to improve and enhance the agency’s census and survey programs. Research strives to increase the efficiency, accuracy, and quality of official estimates by improving statistical and survey methodology.

NASS's Research and Development Division is located in Washington, DC, and has about 34 permanent Federal researchers working on various statistical, methodological, and geospatial research projects. Additionally, NASS augments its research capacity by seeking input from academics by contracting with them or entering into cooperative agreements.

NASS does special tabulations of its data in response to requests and makes unpublished data available in Data Labs to other government agencies and university researchers. Advanced security technology allows such access to data, which is tightly controlled and monitored to ensure all output retains the confidentiality of the farmers' individual information.

Advanced geospatial technology has made it possible to deliver the NASS Cropland Data Layer (CDL) to users for their own research and analysis. CropScape and VegScape, state-of-the-art portals, feature web-based interactive map visualizations, disseminations, and querying systems. The portals are available on the NASS website.

### **9.3. Downstream Outcomes**

- **Data Collection Enhancements:** In FY 2016 NASS implemented a new Computer Assisted Personal Interviewing (CAPI) solution: the Mobile Optimized Survey Tool (MOST). MOST incorporates NASS's previous CAPI functionality but uses new technical advancements to mitigate cellular signal coverage while adhering to the original terms for security requirements, meaning no data will be stored on the hard drive of the mobile device. Like NASS's previous CAPI implementation, MOST relies on iPads but affords NASS significant added functionality:

(1) reduced the reliance on cellular or WiFi by downloading the interviewer's entire sample when service is available, and waiting to upload completed survey data when service is available, (2) incorporates improved survey methodological features, such as automated guides, summing, and question routing logic, (3) a mapping feature that provides interviewers with turn-by-turn directions to sampled farms, (4) functionality for additional surveys, namely the June Area Survey and Objective Yield Surveys, and (5) mobile device management that provides inventory control (of the iPad devices) and the ability to monitor the security settings of the devices.

- **Data Collection Enhancement:** NASS migrated the Crop Progress and Condition Survey (CPCS) data collection activities from a legacy system to a new enterprise web-based solution used to collect data for other NASS surveys. This effort standardized CPCS data collection, reduced support costs by streamlining the agency's architecture, and eliminated a security vulnerability associated with an aging hardware solution.
- **Comment Management Tool (CMT):** High response rates are critical to the quality of the censuses and surveys NASS conducts. Despite NASS's best efforts, response rates have been declining. This tool will be used to store what NASS defines as data-collection comments. These are comments that will assist with, or serve as a reminder for, our interviewers for key information about operators to benefit future visits and cooperation. Other proven ways of improving response rates are to ensure that sampled farm operations are assigned to the most appropriate data-collection mode at the beginning of the survey and for interviewers to have comments about operations (obtained from previous interviews) available to them at the time of the interviews. In FY 2016, NASS implemented the Comment Management Tool (CMT), which

is integrated with other NASS systems to provide an efficient means of assigning data-collection modes and providing interviewers with comments from previous interviews. These features enhance NASS's ability to obtain the highest response rates possible, which improves the overall quality of the survey results.

- **Survey Management Services (SMS):** In 2015, NASS implemented an enterprise level, centralized database with a thin-client application services system designed to prepare survey samples for data collection, including activities such as interviewer assignments, mail file and label generation, survey coordination, check-in, and historical data manipulation. SMS provides an interface for authorized users to develop an overall data-collection strategy for a survey while having access to and using available historical response/non-response data. The data-collection strategy provides the general parameters or information needed to distribute the sample to the selected modes of data collection (mail, Computer Assisted Web Interview (CAWI), Computer Assisted Personal Interview (CAPI), Computer Assisted Telephone Interview (CATI)) in the data-collection preparation phase.
- **Estimation Enhancements:** NASS is examining the practice of web scraping or web crawling techniques to identify non-traditional agricultural farms to improve coverage of our list sampling frames. Web scraping is an automated process for harvesting large amounts of data from websites. In 2016, NASS partnered with the Multiple Agency Collaboration Environment (MACE) to develop software, integrate data sources, and produce recommendations that will help USDA improve awareness and accountability of the local food market and urban farms. The MACE is a consortium of government agencies and contractors that focuses on developing and executing innovative methodologies to solving complex data problems for its partners and

customers. The effort will evaluate and implement new technologies to harvest open source information to identify urban farms, farming entity providers to farmers markets, roadside stands, Community Supported Agriculture (CSA) initiatives, and restaurants who in turn directly sell to consumers in local markets. NASS's overall goal is to develop in-house algorithms to automatically harvest data from these open sources to assist with list building efforts for all types of farms. In addition, the lists derived from this approach will result in an independent list of farm operators which can be used in a capture-recapture estimation model. This estimation approach was used to adjust for coverage in the 2015 Local Food Marketing Practices Survey conducted by NASS.

- **Estimation Enhancements.** NASS is examining model-based estimation techniques to improve the statistical reliability of published forecasts/estimates and error measures. This effort includes research on: (1) time series techniques to model hog and pig estimates as well as labor estimates, (2) Bayesian hierarchical models that combine multiple data sources to produce estimates of yield for corn, soybeans, and wheat, and (3) small-area estimation techniques to model county-level estimates of cash rental rates for pastureland, irrigated cropland, and non-irrigated cropland; harvested corn and soybean acreage; and corn and soybean yield. In 2013, NASS implemented a capture-recapture estimator to improve coverage, nonresponse, and misclassification adjustments for the Census of Agriculture. The methodology ensures the tabulations from the Census of Agriculture are unbiased. Measures of statistical variability are being produced for county estimates. In 2015, the capture-recapture estimator was used to provide estimates for the Organics Survey and, in 2016, it was used for the Local Food Marketing Practices Survey.

- **New Automated Stratification Method for Area Frame Construction:** An innovative and automated stratification method based on satellite-derived land cover data was recently developed and implemented for Area Sampling Frame construction. The method utilizes United States Geological Survey (USGS) National Land Cover Data (NLCD), USDA Farm Service Agency's Common Land Unit (CLU) data, and NASS's geospatial Cropland Data Layers, which are derived from NASA satellite remote-sensing data. This automatic and objective stratification method integrates the traditional Area Sampling Frame construction process with Geospatial Information Technology and existing geospatial information. As a result, the Area Frame's accuracy, efficiency, and objectivity is substantially improved. New Area Frames for Oklahoma, Arizona, New Mexico, Georgia, South Dakota, Alabama, North Carolina, Wisconsin, and Nebraska have been built using this more automated stratification method. Based on June Area Survey reported data, the average accuracy improvement is 29 percent for the eight (reports to date) Area Frames built using the new method. The automated stratification method research has been presented at domestic and international conferences and published in four international conference proceedings and in two peer-reviewed journals.
  
- **New Imputation Methodology for the Agricultural Resource Management Survey (ARMS):** Iterative sequential regression (ISR) is a multivariate normal imputation method, providing flexible model specification for missing survey response and the ability to handle continuous and semi-continuous data. This imputation method is the result of a 2-year collaborative agreement between NASS and the National Institute of Statistical Science (NISS) to investigate improved imputation methodology for phase three of ARMS (ARMS-III). ARMS-III is an annual survey sponsored by NASS and the Economic Research Service (ERS) and provides a summary of detailed farm characteristics and financial information with respect to

operations, practices, and household financial well-being. Both the sensitive nature of this survey and its length make non-response of particular variables non-ignorable. This methodology was implemented in 2015 for the 2014 ARMS-III survey, improving the quality of imputed data over the prior conditional means imputation approach. Micro-data quality has been improved by preserving relationships between variables, allowing for researchers to make new discoveries and better policy decisions. By preserving the distribution of survey responses, ISR has improved the quality of the survey indicators to better reflect uncertainty from non-response. The research into ISR has culminated with the publication of 2 peer reviewed journal articles, 10 conference proceedings, 1 technical report, and 1 publically released open source software package.

- **Development of Open Source Software.** NASS has developed open source software applications to assist in accessing NASS products, in support of scientific publications and for the development of NASS products. In 2016, this work culminated in the publication of four software packages through the Comprehensive R Archive Network (CRAN), a public repository of open source software packages written in the R programming language. These four software packages include: *inca*, a package for integer calibration; *saAlloc*, a package for simultaneous allocation and stratification; *cdlTools*, a package for accessing Cropland Data Layer raster images and calculating zonal statistics; and *ISR3*, a package for multivariate normal imputation. As of November 2016, these 4 packages account for approximately 500 downloads per month. The contribution of these packages to the open source community has helped in promoting NASS research and has allowed for an additional mode of collaboration with the public. The code within these packages may also be considered as a contribution to the Office of Management and Budget (OMB) memorandum M-16-21 “Federal Source Code Policy:

Achieving Efficiency, Transparency, and Innovation through Reusable and Open Source Software.”

- **New Geospatial Products:** Information on future crop-specific planting is valuable for improving agricultural survey estimates. NASS recently developed new U.S. geospatial land cover products, called “Crop Planting Frequency Data Layers,” based on the 2008-2015 NASS Cropland Data Layers. In this work, crop planting frequency or crop frequency is defined as the number of years that a 30-meter pixel is classified to a specific crop over a given period. Crop planting frequency data layers for corn, soybeans, wheat, and cotton were successfully generated, evaluated, and provided on NASS’s online operational geospatial application entitled CropScape, which is located at <http://nassgeodata.gmu.edu/CropScape>. The accuracies of the publically available national scale 2008-2015 Crop Frequency Data Layers are 83.95 percent, 84.01 percent, 83.75 percent, and 73.16 percent for corn, cotton, soybean, and wheat, respectively. The Crop Frequency Data Layers provide a new data source for area sampling frame stratification research and imputation research. These newly developed land cover products are an enhancement in service since they are now available to the public to visualize, analyze, and download on CropScape for environmental assessments, healthcare, bioenergy production research, and food production decision support.

#### 9.4. Outreach Activities

- **Enhanced Data Visualization of Statistical Reports:** NASS produces vast amounts of data from more than 400 agricultural surveys it conducts each year. These data are available to the public via a Quick Stats database and reports that the agency posts online in .pdf, .txt and .csv

formats. The goal of the project is to reform pieces of the data dissemination process to include more easily digestible and reusable visual representations of the data products NASS releases and increase the speed to which they are available. The visuals will be reusable in many ways both internally and externally, providing the public with a useful and timely data product created by a NASS specialist. Internally, we will streamline the production process, eliminating duplicative steps and product delivery delays. NASS has created an online, dynamic, shareable data visualization. The visualization, which shows production for a number of agricultural items over time and geography, saves time, and enhances data accessibility, usefulness, and customization, and is beginning to improve customer satisfaction with NASS data products. Comments from data users are positive, and we will conduct a customer satisfaction survey in January 2017 to gauge change in satisfaction before and after the project. In fact, the Foresee Customer Satisfaction Benchmark index for our website, which features this visualization product, has increased since the beginning of this project from 61 to 64. Additionally, Twitter followers increased 3,536 from 23,400 to 26,936. Twitter was our primary means of promoting the visualization. Data visualization site hits are holding steady at just over 1,400 per month from February-June 2016 when we started tracking it. We had an increase in April to 3,200, likely because we promoted new crop data in the visualization via Twitter at that time.

- **Data User Input:** NASS holds an annual data-users meeting to gather input to ensure the agency statistical program is meeting the needs of our user community. The 2016 Data Users Meeting was held in Chicago, Illinois, on October 18, 2016. It featured representatives from NASS as well as other USDA agencies and provided an open forum for data users to ask questions about the entire USDA statistics program. From a customer service perspective, the meeting provided an excellent opportunity for NASS to learn about data users' concerns and

desires for improvements or changes to the statistics and economics programs.

## 9.5. Publications

Peer Reviewed Scientific Publications .....6 entries

- Assaf, S.; Campostrini, S.; Xu, F.; and Gotway Crawford, C. (2016) “Analysing behavioural risk factor surveillance data by using spatially and temporally varying coefficient models.” *Journal of the Royal Statistical Society Series A*, vol. 179, pp. 153-175.
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Trade Journal Publications.....0 entries

## **10. The Natural Resources Conservation Service (NRCS)**

<http://www.nrcs.usda.gov>

### **10.1. Mission Statement**

The Natural Resources Conservation Service (NRCS) is not generally considered a research agency—the thrust of its mission is to help private landowners address natural resource concerns on their lands. In order to carry out this mission, however, NRCS has become perhaps the country’s premier agency for transfer of natural resources conservation technology. NRCS maintains approximately 160 National Conservation Practice Standards

([http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/technical/cp/ncps/?cid=nrcs143\\_026849](http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/technical/cp/ncps/?cid=nrcs143_026849)).

These standards and supporting documents are NRCS’s principle vehicle for transferring the latest science and technology directly to America’s farmers and ranchers.

### **10.2. Nature and Structure of Programs**

Once resource needs on private farms and ranches have been identified, the agency works closely with the Agricultural Research Service and numerous universities to develop and fine tune the science and technologies needed to help farmers conserve, protect, and enhance their natural resources. The NRCS also conducts conservation field trials to strengthen NRCS technology when formal research is not available. As appropriate, these trials are conducted on working farms and ranches, in cooperation with other agencies and organizations. A field trial is a study designed to examine the adequacy or adaptability of a conservation practice, technology, procedure, or material. It may also be used to introduce promising conservation practices or technologies into areas where they are not now accepted

as a solution to a local soil, water, or related natural resource problem or condition. Field trials can be useful to transfer technology, to update the local technical guide, or to show the need for formal research.

Although NRCS is not known as a research agency, it does carry out and support research through its Soil Science Division. In addition, NRCS's Conservation Innovation Grants program is one of the key vehicles for technology transfer of innovative conservation approaches and technologies.

### **10.3. Downstream Outcomes: Soils Research and Technology Transfer**

The NRCS Soil Science Division is authorized by the U.S. Secretary of Agriculture to conduct research on the use and behavior of soils to facilitate soil classifications and distribution of information through the Web Soil Survey and other vehicles of data dissemination. Below are some examples of research and Technology Transfer that are currently underway.

### **10.4. Outreach Activities**

#### **NRCS Conservation Innovation Grants (CIG)**

An important vehicle for development of conservation technology that NRCS will transfer to farmers and ranchers is Conservation Innovation Grants

[\(http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/cig/\)](http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/cig/)

CIG, a component of NRCS's Environmental Quality Incentives Program (EQIP), is a voluntary program intended to stimulate the development and adoption of innovative conservation approaches and

technologies while leveraging Federal investment in environmental enhancement and protection, in conjunction with agricultural production. Under CIG, EQIP funds are used to award competitive grants to non-Federal governmental or nongovernmental organizations, tribes, or individuals.

CIG enables NRCS to work with other public and private entities to accelerate technology transfer and adoption of promising technologies and approaches to address some of the Nation's most pressing natural resource concerns. CIG will benefit agricultural producers by providing more options for environmental enhancement and compliance with Federal, State, and local regulations. NRCS administers CIG. Much of what NRCS learns from CIG is incorporated into conservation practice standards, used by the field conservationists and technicians to address resource concerns on private farms and ranches.

A sample of project results is provided below. Lists and brief summaries of funded projects are available on the CIG Web site (<http://www.nrcs.usda.gov/technical/cig/index.html>).

## **11.0 National Institute of Food and Agriculture (NIFA)**

<http://www.nifa.usda.gov/>

### **11.1 Mission and Vision Statements**

NIFA's mission is to "Invest in and advance agricultural research, education, and extension to solve societal challenges." NIFA approaches its mission with the following vision: "Catalyze transformative discoveries, education, and engagement to address agricultural challenges."

### **11.2 Nature and Structure of Research Program**

NIFA's two key mechanisms for accomplishing its mission are:

- National program leadership. NIFA helps States identify and meet research, extension, and education priorities in areas of public concern that affect agricultural producers, small business owners, youth and families, and others.
- Federal assistance. NIFA provides annual capacity grants to land-grant universities and competitively granted funds to researchers in land-grant universities, other universities, and other partner organizations.

NIFA collaborates or has formal working partnerships with many institutions and individuals. Our key partners are the institutions of higher learning making up the Land-Grant University System. However, we also partner with other Federal agencies, within and beyond USDA; non-profit associations;

professional societies; commodity groups and grower associations; multistate research committees; private industry; citizen groups; foundations; regional centers; the military; task forces; and other groups.

NIFA and its partners focus on critical issues affecting people's daily lives and the Nation's future. The advanced research and educational technologies NIFA supports empower people and communities to solve problems and improve their lives on the local level.

Among the many programs NIFA leads, many are currently focusing efforts on the following societal challenges:

- Advance our ability to provide global food security and fight hunger
- Create a resilient and environmentally sustainable agricultural system responsive to climate change
- Enable U.S. energy independence through the development of sustainable bioenergy feedstocks and value-added bio-based industrial products
- Combat childhood obesity by ensuring the availability of affordable, nutritious food and providing individuals and families science-based nutritional guidance
- Reduce the incidence of food-borne illness and provide a safer food supply

NIFA does this not only through its research and higher education programs, but also through an extensive network of State, regional, and county extension offices in every U.S. State and territory. These offices have educators and other staff who respond to public inquiries and conduct informal, noncredit workshops and other educational events. Extension education for all citizens is also provided nationally online through eXtension.org.

Moreover, with support from more than 500,000 4-H volunteers (USDA's 114-year-old youth development program administered through NIFA) engages more than 6 million young people every year and teaches them life skills through hands-on learning and leadership activities.

### **11.3 Current Technology Transfer Goals, Objectives, and Measures of Success (Metrics)**

Applicants or recipients of NIFA grants that support basic research and integrated projects are encouraged to explore potential commercialization through the Small Business Innovation Research (SBIR) program. Conversely, small business owners or other grant recipients are encouraged to use NIFA-funded basic research programs to enhance innovation and competitiveness in their commercial operations.

Each land-grant university funded by NIFA has a university technology transfer office to promote, support, and improve technology transfer from academic and nonprofit institutions. They often manage and license innovations derived from research at their universities (including research funded by NIFA) and are a good source to link small businesses with university faculty. Moreover, the Cooperative Extension System Offices are a nationwide, non-credit educational network. These offices are staffed by one or more experts who provide useful, practical, and research-based information to agricultural

producers, small business owners, youth, consumers, and others in rural areas and communities of all sizes.

#### **11.4 Strengthening Current Activities and New Initiatives**

The National Institute of Food and Agriculture (NIFA) administers the USDA Small Business Innovation Research (SBIR) program. In FY 2016, NIFA promoted SBIR funding opportunities to USDA intramural research Cooperative Research and Development Agreement (CRADA) partners through a partnership between NIFA's SBIR program and the USDA's Agricultural Research Service (ARS) Office of Technology Transfer (OTT).

Through this partnership with ARS, NIFA informs potential SBIR applicants of partnership possibilities and benefits working with ARS scientists. If ARS and a small business identify an opportunity to partner together, the small business would submit an SBIR application and would address this partnership. The partnership is generally developed under a CRADA or through a licensing agreement between ARS and the small business. NIFA in turn uses the knowledge of an ARS CRADA or license as a tie-breaker in the application selection process. Some of the benefits a small business can employ when partnering with ARS is joint intellectual property potential. In this case, ARS can file patent applications for CRADA partners and only charge the partner for filing fees, patent application, and prosecution completed by registered USDA patent agents provided free of charge, saving small businesses substantial costs.

#### **11.5 Response to Presidential Memorandum on Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Business**

**USDA 27: New Metrics (beginning FY 2014) on NIFA outcomes:**

Efforts to develop procedures for requesting information from NIFA awardees are in progress.

Information will be collected on: (1) number of new jobs created by a small business as the result of receiving SBIR grant funds; (2) increase in sales of technology or services developed by a small business as the result of receiving SBIR grant funds; and (3) sale to other businesses of licenses to technology developed by a small business as the result of receiving SBIR grant funds.

The data on the patents issued based upon Competitive NIFA Funding have been collected for FY 2015 and are now being reported (see Table 1).

**Table 1.** Patents Issued in FY 2016 based upon Competitive NIFA Funding.

<b>Institution Name</b>	<b>Award Number</b>	<b>Patent Number</b>	<b>Issue Date</b>	<b>Invention Description</b>
Colorado State University	2912-34141-20309	5,253 (PVP Certified)	5/16/2016	AAC Spendor Russet
Colorado State University	2012-34141-20309	5,254 (PVP Certified)	5/16/2016	AAC Stout
University of Wisconsin, Madison	2006-35504-17436	9,150,869	10/6/2015	Sugar Transport Sequences, Yeast Strains Having Improved Sugar Uptake
University of Wisconsin, Madison	11-CRHF-0-6055	9,180,168	11/10/2015	Use of Glycomacropptide to Improve Women's Health
University of Wisconsin, Madison	2001-335204-10184	9,180,181	11/10/2015	H3 Influenza A Virus
University of Wisconsin, Madison	11CRHF-0-6055	9,187,790	11/17/2015	Saccharification of Lignocellulosic Biomass
Michigan State University	20008-51110-04352	9,193,514	11/24/2015	Product Packaging System with Antimicrobial Agent
Auburn University	2009-34605-19805	9,201,048	12/1/2015	Systems for Characterizing Resonance Behavior of Magnetostrictive Resonators
Mississippi State University	Capacity Funding	9,222,032	12/29/2015	Composition and Methods for Improved Fuel Production
Cornell University	2005-35100-16044	9,238,680	1/19/2016	Engineering Heat-Stable Disease Resistance in Plants

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University of Wisconsin, Madison	2005-35503-16303	9,254,266	2/9/2016	Inhibiting Surface Enhanced Crystallization of Amorphous Pharmaceuticals
Cornell University	2005-35603-15298	9,267,220	2/23/2016	Nanofibers, Nanotubes and Nanofiber Mats Comprising Crystallizing Metal Oxides
University of Wisconsin, Madison	11-CRHF-0-6055	9,282,738	3/15/2016	Antimicrobial Compositions and Methods of Use Thereof
Pennsylvania State University	Capacity Funding	9,289,435	3/22/2016	Anti-Leukemic Property of Cyclopentenone Prostaglandin Metabolite of Omega-3 Fatty
University of Maryland, College Park	2006-34467-17102	9,321,806	4/26/2016	Novel methods for Recovery of Leaf Proteins
University of Wisconsin-Madison	09-CRHF-0-6055	9,322,068	4/26/2016	Methods and Compositions for Improved Fertilization and Embryonic
Michigan State University	2005-35504-16195	9,328,335	5/3/2016	A Method to Produce Acetyldiacylglycerols (Ac-Tags)
Auburn University	2010-34605-20651	9,335,292	5/10/2016	Electrochemical Proximity Assay
Michigan State University	2004-34158-15188	9,371,539	6/21/2016	DNA Encoding Ring Zinc-Finger Protein and the Use of the DNA in Vectors
University of Wisconsin-Madison	05-CRHF-0-6055	9,371,562	6/21/2016	Methods and Compositions for Genetically Detecting Improved Milk Production
Mississippi State University	2004-35204-14211	9,375,467	6/28/2016	Live Attenuated Catfish Vaccine and Method of Making
Cornell University	Capacity Funding	9,376,668	6/28/2016	Fagopyritol Synthase Genes and Uses Thereof
University of Wisconsin-Madison	05-CRHF-0-6055	9,422,608	8/23/2016	Methods and Compositions for Improved Cattle Longevity and Milk Production
University of Wisconsin-Madison	09-CRHF-0-6055	9,428,770	8/30/2016	Over Production of Secondary Metabolites by Over Expression
University of Wisconsin-Madison	04-CRHF-0-6055	9,446,110	9/20/2016	Vaccine Candidates Against Johne's Disease
University of Minnesota	Capacity Funding	PP26600	4/12/2016	Rhododendron Plant Named "UMNAZ 493"
University of Minnesota	Capacity Funding	PP26601	4/12/2016	Rhododendron Plant Named "UMNAZ 502"

**USDA 28: Partner with ARS and the Animal and Plant Health Inspection Service (APHIS) at  
USDA on the National Plant Diagnostic Network and the National Animal Health  
Laboratory Network**

There are two goals for NIFA in this area.

- (1) Develop competitive funding opportunities to include ARS scientists in the development of diagnostic assays and validation protocols that are needed to support APHIS regulatory surveillance efforts for foreign and emerging plant and animal diseases. Plans for FY 2017 are under development.
  
- (2) Coordinate APHIS regulatory and ARS research efforts with relevant components of the Cooperative Extension Service in order to better identify producer needs and the transfer of relevant technology. Plans for FY 2017 are under development.

### **11.6 Downstream Outcomes**

**Stony Creek Colors** has received support from the SBIR program. It is located near Nashville, TN, and it is developing agronomic procedures for growing indigo plants and chemical processing procedures for extracting the natural indigo dye from these plants. Next summer it will have 30 farmers growing 180 acres of indigo. The company opened a 20,000 sq. ft. processing facility where the indigo dye is produced. It is working with Levi Straus, who will buy the natural indigo dye for production of a line of jeans that are produced using the natural dye. Stony Creek Colors is also in touch with Sensient, a major company that deals with both natural and synthetic pigments, and will explore the possibility of using

the indigo dye for various food applications. Stony Creek Colors team members have received considerable publicity. They were selected to make a presentation at the Ag Innovation Showcase in St. Louis in 2015, and recently they received the Martha Stewart American Made award.

**Altaeros Energies** with support from the SBIR program has developed a Buoyant Airborne Turbine (BAT) for production of wind energy in remote locations. Wind speed is stronger and more uniform at 1,000 feet than at ground level. The BAT is filled with helium and maintained at 1,000 feet, where the wind turbine produces electricity that can be fed into a micro-grid to provide clean and sustainable energy for remote isolated communities. There is considerable interest in this technology in Alaska and the company has received a \$7 million investment for future deployment of the BAT system in Japan. Altaeros Energies was featured in CNN's 2014 edition of The CNN 10: Inventions.

Consumer demand for safe, high-quality, additive-free packaged foods is growing. Thanks to two recent investments in innovative food processing technology based on microwave energy, **Washington State University** (WSU) is advancing toward meeting this demand. The Agriculture and Food Research Initiative (AFRI) program awarded WSU \$4 million to establish a Center of Excellence that will accelerate the technology transfer to mainstream commercial markets. This is the first Center of Excellence on Food Safety Processing Technologies funded by AFRI. In addition, the Australian Government has announced a \$7.2 million investment to adopt microwave-assisted thermal sterilization (MATS) technology. WSU and industry partner 915 Labs will provide the system to Australia's Ministry of Defence. Both investments will improve ready-to-eat meals for convenience-oriented consumers and soldiers alike.

On November 14, 2016, U.S. Secretary of Agriculture Tom Vilsack was part of a welcoming committee that met Alaska Airlines Flight 4 as it arrived at Washington DC's Reagan National Airport from Seattle Tacoma International Airport. The arrival marked the first commercial flight powered with cellulosic biofuel (20% blend with traditional jet fuel) derived from forest residuals. The biofuel was only one of many successful outputs of the **Northwest Advanced Renewables Alliance led by Washington State University**. The 5-year project, initiated in 2011, was funded through USDA-NIFA AFRI's Coordinated Agricultural Projects program. Thirty-two member organizations contributed to NARA's effort to create economically, environmentally, and socially sustainable bioproducts from unused limbs and branches from forestry operations. Education and extension efforts resulted in programs that reached 38,724 K-12 students, 845 teachers, 213 undergraduate students, 199 graduate students, and 380 stakeholder groups. The project produced 44 refereed and/or extension publications, 135 news stories, 250 conference presentations, and posted over 300 social media posts. In addition to these project outputs, the Alaska Airlines flight was the biggest news story of the year for the airline both in traditional and social media, generating 313 articles, 200 broadcast stories, and 22,000 likes, shares, and social media comments within 48 hours of the flight.

A **Pennsylvania State University** project will test whether a nanotechnology micro-device can be adopted to trap and concentrate plant viruses for early detection of plant diseases that currently cause crop losses. Crops may look healthy to a human observer while they may be actually infected by a number of deadly plant viruses. The concentration of the virus in the plant's sap often is too low to detect with current techniques. The virus' size (only 1/500th the diameter of a human hair) presents a diagnostic challenge. However, the emerging science of nanotechnology allows the manipulation of matter at the atomic scale and offers some possible solutions. The micro-device (known as the carbon nanotube size-tunable enrichment platform, or CNT-STEP) originally was developed by researchers in

the Department of Physics in Penn State's Eberly College of Science and the College of Engineering, Department of Bioengineering. This project's goal is to adapt this nanotechnology micro-device to concentrate pathogens in plants, insects, and other organisms so that modern diagnostic procedures can be employed earlier in an infection cycle when virus levels otherwise may be too low to detect. This technology has the potential to catch infections in the early stages when growers can manage them more easily and effectively with reduced pesticide use. This project is funded through the Crop Protection and Pest Management program, Applied Research and Development Program Area.

The **Western Integrated Pest Management (IPM) Center** brings together the expertise needed to successfully address high-priority pest-management issues facing farmers, pest managers, communities, and others in the Western United States. The Western IPM Center's food-security signature project, Regional Infrastructure for Climate and Weather-based Decision Support Tools, established web-based tools that combine U.S. weather data with plant pest and disease models to serve many decision-support needs in U.S. agriculture (<http://uspest.org/wea>). The site now has more than 27,000 public weather stations linked to more than 127 different pest and crop models. The website has run more than 388,696 degree-day model runs and approximately 310,000 hourly weatherly-driven model runs for users since project inception. These degree-day models allow users to forecast when pests should be managed by modeling the effects of weather and lifecycle information. New features added to the extended forecasting functionality include the 10-year average station data, which uses the National Oceanic and Atmospheric Administration's North American Multi-Model Ensemble forecast system and generates predictions for up to 7 months. This regional infrastructure for climate and weather-based decision-support tools provides daily and hourly weather-driven models serving IPM, regulatory, and plant biosecurity uses nationally, and specializes in IPM needs for the West. The Western IPM Center is funded through NIFA's Crop Protection and Pest Management Program.

A **University of Florida** project demonstrated the efficacy of methyl bromide alternatives for small fruit (strawberry) and vegetable (tomato) production in Florida for the management of weeds and soilborne pests and pathogens. This project was supported by the Methyl Bromide Transition Program that supports the discovery and implementation of practical pest management alternatives for commodities and uses affected by the methyl bromide phase-out. In Florida, field trials demonstrated that supplemental application of chloropicrin decreased the incidence of the plant disease, Fusarium wilt, over the grower treatment standard, leading to a 21- to 23-percent increase in tomato yields. The reduction of reduced the incidence of Fusarium wilt by 26 to 77 percent compared to the grower treatment standard. The supplemental application of chloropicrin at the recommended rate of 150 lbs/treated acre added \$183 to the cost per treated acre.

A **Michigan State University** project successfully established the first “proof of concept” for the use of trunk injection technology for controlling disease and insect pests of U.S. apples. The study demonstrated a range of insecticide and fungicide compounds that can be delivered via trunk injection for protection of apple trees. The pesticide rate studies showed that reduced rates of pesticides can be used with trunk injection to provide season-long, and in some cases multiple seasons of pest control. With current commercially available injection tools, the seasonal application time for trunk injection is 3.5-6 times more than using a ground sprayer. However, based on the pesticides tested with trunk injection, the economic analysis suggests a \$271 per acre savings in season-long pest management program costs in central leader apple production systems and break-even expenses for vertical axe production systems. The Pest Management Alternatives program funded the research.

Respiratory tract infection in pigs, commonly referred to as "Porcine Respiratory Disease Complex (PRDC)," is a major challenge for the swine industry as it causes significant production and economic losses to producers worldwide. Timely detection of causative agents is required to minimize the spread of infection and reduce economic losses. Current diagnostic methods are not suitable for field use because of the need for expensive equipment, highly trained personnel, and a specialized laboratory. Rapid molecular diagnostic test kits have not been available for veterinary use in the field or in small clinics that lack infrastructural support. To address this unmet need, **Lucigen** received SBIR support to develop an easy to use "sample-to-answer" molecular diagnostic device for penside detection of the three viral pathogens associated with PRDC: porcine reproductive and respiratory syndrome virus (PRRSv), swine influenza virus (SIV), and porcine circovirus type 2 (PCV-2). Using its proprietary thermostable OmniAmp® polymerase, and performed on a simple, easy to use automated molecular detection platform developed by Lucigen. The researchers developed an assay based on loop mediated isothermal amplification (LAMP). Total assay time of 40 minutes with minimal hands-on time and without need of any additional equipment, such as pipettes, centrifuge etc., was attained. Results are displayed on-screen as positive or negative for a specific pathogen, minimizing errors caused by user interpretation. This diagnostic device has been designed so that people without any specialized training can use it to perform the assay. Once developed, this technology will be used to rapidly develop diagnostic assays for point-of-care detection of additional veterinary pathogens. Development of this innovative molecular diagnostic device significantly improves the ability of producers to monitor the health of their animals in real time without incurring significant testing costs. Use of this technology will be economically beneficial to producers, as this will allow them to test samples at penside, saving them money in terms of testing and shipping costs as well as time.

**National 4-H** staff is active on the White House Maker initiative and in fostering making and inventing activities in 4-H. Several States have been developing maker experiences in 4-H clubs, afterschool programs, camps, and military 4-H partnership programs. The 4-H “Science, Technology, Engineering and Mathematics” (STEM) National Program Leader (NPL) co-coordinated a USDA booth at the National Maker Faire held at University of the District of Columbia where two local 4-H clubs and one USDA agency presented examples of their maker activities. With assistance from 4-H National Headquarters, National 4-H Council hosted the third National Youth Maker Summit in November 2016, which was attended by 80 4-H members, staff, and volunteers from across the country. About 90 4-H professionals attended a technology workshop presented by 4-H STEM NPL called “Up, Down and All Around” using virtual reality, 360° video and gesture controllers in January 2016. National and State 4-H staff representatives coordinated the National 4-H Geographic Info Systems (GIS)-Global Positioning System (GPS) leadership team composed of teens and adults from four States. The team continued development of an online GIS 4-H history map where local clubs can map their 4-H historic places of interest. The NPL presented this map in an e-poster session at the 2016 national meeting of 4-H professionals. Currently, the team is also developing a series of maps related to health and food access issues. NASA and 4-H National Headquarters began collaborating on the NASA GLOBE Observer citizen science program, where youth and adults will use mobile apps to collect data about clouds, mosquitos, landcover, soil and other subjects to contribute to NASA earth science data collections. A team of 4-H teens and educators are assisting in the program development. Cornell University, 4-H National Headquarters, and National 4-H Council collaborated on the 2016 4-H National Youth Science Day project “Drone Discovery.” In events across the country, young people learned about drones and how they can be used to support agriculture and natural resources. They used a foam glider with keychain video camera attached to learn about how drones capture aerial imagery for analysis. They

then used a Scratch program simulation to program a simulated drone over a landscape to efficiently gather data to solve an issue, such as infestation in a corn field.

**North Carolina State University** (NCSU) is leading a Coordinated Agricultural Projects (CAP) project (The USDA-NIFA Food Virology Collaborative, or NoroCORE), the purpose of which is to reduce the burden of human illnesses caused by foodborne viruses, through research, education and extension activities. Noroviruses are the leading cause of foodborne disease, responsible for about 5.5 million cases per year in the United States. When combined with other transmission modes, there are estimated to be over 20 million norovirus cases annually in this country. There are a number of technology transfer activities associated with the NoroCORE project, as described below.

- Our most significant output this year was report of a cell culture model for growing human norovirus in the laboratory. Producing human norovirus in the laboratory has been an ongoing challenge for five decades, and this development will change the scientific landscape and accelerate efforts to decrease disease burden. This work was performed by NoroCORE team members from Baylor College of Medicine and reported in the September 2016 issue of *Science*. The system has been adopted by laboratories at U.S. Centers for Disease Control and Prevention (CDC) and U.S. National Institute of Health (NIH), as well as by a few academic laboratories. Efforts are underway to implement the system in food virology laboratories (U.S. Food and Drug Administration and academic) during 2017. This work was jointly funded by USDA-NIFA and the NIH.
- As reported previously, various NoroCORE-affiliated institutions have identified specific molecules that can be used to facilitate norovirus capture and detection, including engineered

antibodies, peptides, nucleic acid aptamers, and synthetic glycans. Many of these molecules have been shared amongst NoroCORE collaborators, and some studies are underway to compare their performance. Several are now patent-protected, and negotiations for licensing to commercial entities continue.

- The Illinois Institute of Technology, Institute for Food Safety and Health (IFSH) team continues to work with end-users (food and equipment manufacturers) to validate commercially relevant methods to inactivate noroviruses in the food supply. North Carolina State University investigators also continue their work with small and medium-sized companies in the sanitation and hygiene sector to systematically evaluate the anti-noroviral efficacy of sanitizers and disinfectants relevant to the food sector.
- During 2016, NoroCORE collaborators from Clemson University, North Carolina State University, and Research Triangle Institution (RTI) International developed a set of training modules on foodborne transmission of norovirus designed for State and local public health professionals. The same group also developed editable guidelines aimed at small, independent restaurants for cleanup of human bodily fluid contamination events in their facilities. These efforts have been undertaken with substantial input from stakeholders so as to be relevant to target audiences.

The **University of Nebraska** is leading a CAP project to reduce foodborne illnesses from Shiga toxin-producing *E. coli* (STEC) through research, education, and extension activities. Shiga toxin-producing *Escherichia coli* (STEC) are major pathogens of humans, most commonly acquired through the consumption of contaminated food or water, with about 29 percent of the cases in the United States attributable to beef. There are a number of tech transfer activities, for example:

- The effectiveness of peroxyacetic acid (PAA) in multiple use formats (i.e., after opening of vacuum-packaged subprimals before mechanical tenderization, and use in concentrations from 0-1,800 parts per million (ppm) as chilled subprimal washes) for controlling STEC-7 was evaluated to provide guidance to beef processors on effective critical control point (CCP) parameters. Studies found 400 ppm PAA was ineffective at further reducing STEC-7 when applied to chilled subprimals after 24-hour vacuum-packaged storage in the presence of 250-500 ppm lauric arginate, which alone resulted in 1.5-1.7 log CFU/cm<sup>2</sup> STEC-7 reductions. Application of increasing concentrations of PAA on chilled subprimals prior to vacuum-packaged storage showed a maximum reduction of 0.9 log CFU/cm<sup>2</sup> at 600-800 ppm, with no additional reductions until PAA  $\geq$  1600 ppm was reached.
- A study evaluating water and energy use in a beef packing plant, with emphasis on antimicrobial interventions, to provide baseline data for comparison of new intervention technologies developed by researchers, was completed. The results of this study have led to the implementation of methods for more efficient use of water and energy: rain water collection from cattle pens; replacement of inefficient toilets; insulation of hot water pipes; installation of quick-connect nozzles; and implementation of a wastewater heat exchanger to be used for carcass washes. Implementation of these methods resulted in the plant reducing water use from 487 gal/head in 2014 to 471 gal/head in 2016. Attempts to expand the studies and implement similar methods to increase efficiency of water and energy use in other and larger plants are in progress.
- Online training programs for STEC and pre-harvest food safety were developed and made available at <https://www.animalcaretraining.org/PackageDetail.aspx?type=STEC>.

This program consists of 11 modules that allow individuals to be trained in pre-harvest and post-harvest STEC prevention, and includes modules on beef and veal. The modules have the ability to provide tracking of employee training electronically, and they have been made available in both English and Spanish. The modules are as follows: (1) STEC Introduction; (2) STEC Restaurant; (3) STEC Distributor; (4) STEC Cull Dairy; (5) STEC Feedlot; (6) STEC Small Packer; (7) STEC Veal Biosecurity; (8) STEC Veal Housing; (9) STEC Veal Feed and Water Management; (10) STEC Veal Calf Scours; and (11) STEC Veal Transportation.

Researchers at the **University of Connecticut** are studying ingestion, bioaccumulation, and depuration of titania nanoparticles by two bivalves, the blue mussel (*Mytilus edulis*) and the eastern oyster (*Crassostrea virginica*). Sedentary aquatic organisms are vulnerable to anthropogenic contaminants, such as nanoparticles, that enter coastal environments. Nanoparticles were delivered to the animals either incorporated into marine snow or added directly to seawater. After feeding, animals were transferred to filtered-seawater and allowed to depurate. Feces and tissues were analyzed for concentrations of titanium by inductively coupled plasma-mass spectrometry. Both species ingested about half of the nanoparticles to which they were exposed, and > 90 percent of the nanoparticles were egested in feces within 12 hours, post-exposure. The findings of this study demonstrate that mussels and oysters can readily ingest both Titan and P25 nanoparticles regardless of the form in which they are encountered, but depurate these materials over a short period of time.

Researchers at **Iowa State University** are studying *Campylobacter* associated with poultry processing. Understanding the movement of bacterial pathogens along a poultry processing line is important for identification of potential points on the line where interventions can be directed to reduce pathogens entering the final product. Carcass rinses from various stages of the process line were

examined to determine population levels present and overall prevalence of *Campylobacter*. Of the samples examined, approximately 28 percent were positive for *Campylobacter* spp., with the majority of isolates recovered being identified as *C. jejuni*. Population levels detected ranged from 0.7 to  $>6 \log_{10}$  cfu/ml. The majority of samples that were positive for *Campylobacter* were detected early in the processing line at the pre- and post-scald stages and rehang. Detection following the final dip stage was extremely low. Different plants examined had different prevalence levels and could be categorized into high, medium, and low prevalence plants. These data suggest that interventions at the latter stages of processing have a significant impact in reducing the overall final carcass contamination.

Aaron Dossey from **All Thing Bugs** received support from SBIR and successfully developed a patent pending technology and methodology for generating high quality powder products made from at least 3 species of insects: (1) cricket, (2) mealworm and (3) waxworm. Griopro® cricket powder ingredient product was developed under SBIR Phases I and II. The proprietary Griopro® cricket powder ingredient proved to be a functional and high-quality ingredient in several food and beverage products including: tortillas, pastas, taco meat, sausages, cereals, puffed extruded snacks, baked goods, protein bars, protein shakes, extruded rice pastas, and other products. They were able to successfully demonstrate that incorporation of this ingredient into these products at levels ranging from 15 to 30 percent did not negatively impact any of the products based on structural integrity, color, or aroma. Alternative meats (taco meat, sausage, etc.) can be made using 100 percent insect powders (plus water and seasoning) with no other ingredients.

Low-moisture foods have been implicated in several cases of causing foodborne illness through pathogen contamination. Researchers at the University of Georgia have been studying the dynamics here to gain a better understanding of the survival of *Salmonella* in low-moisture foods. It is believed

that food components play a significant role in the survival and viability of this pathogen. The results of this research can be a valuable tool to both government and industry as a risk assessment for low-moisture products. Thus, manipulation of low-moisture food components may be a means of decreasing pathogen survival. Researchers have completed a project titled “A Predictive Model for the Survival of *Salmonella* in Dry Foods Containing Fat.” The objective of this study was to quantify the influence of fat content on the survival of *Salmonella* in dry foods and use this information to modify an existing secondary predictive model and validate it for low- and high-fat dry foods. Dry foods such as nuts, milk powder, and spices have been associated with illness. *Salmonella* will not grow in dry foods, but can survive for extended periods of time if introduced into the food or the processing steps. Researchers used the Weibull model to describe the data, and a previously developed secondary model was revised to include foods with a fat content  $\leq 50$  percent (w/w) based on the influence of temperature, water activity ( $a_w$ ) and fat content on survival. Predictions were validated in four commercial food products within the range (temperature,  $a_w$ , fat content) of the modeled data. The revised model was useful in predicting survival in low- and high-fat dry foods with a prediction performance that is improved in bias and accuracy compared to the unmodified model. The model shows that fat (20 percent and 50 percent) protected *Salmonella* against heat inactivation at temperatures  $\geq 50^\circ\text{C}$ . The predictive model can be used as a quantitative support tool in risk mitigation strategies for low- $a_w$  foods containing fat.

Pigs and lambs are shown to frequently harbor *Toxoplasma gondii*, which is responsible for 24 percent of foodborne deaths in the United States per year. Those that are reared with pasture access are at an increased risk for exposure to the pathogen. Thus, the popularity of organically raised meat could cause significant public health risk. The Centers for Disease Control and Prevention (CDC) reported that *Toxoplasma gondii* is one of three pathogens (along with *Salmonella* and *Listeria*), which together account for  $>70$  percent of all deaths due to foodborne illness in the United States. Food animals act as

one of the sources for parasite transmission to humans. The Food and Agriculture Organization (FAO)/World Health Organization (WHO) estimated that approximately 22 percent of human *Toxoplasma gondii* infections are of a meat source. Researchers at the **University of Maryland** are studying the prevalence of this protozoan parasite in meat animals. The objective of the current study is to use systematic meta-analysis to provide a precise estimation of *Toxoplasma gondii* infection prevalence in food animals produced in the United States. Four databases were searched to collect eligible studies, where focus was placed on six animal categories by a quality-effects model. A wide variation in prevalence was observed in each animal category. Animals raised outdoors or that have outdoor access had a higher prevalence as compared with animals raised indoors. Results indicate that *Toxoplasma gondii* infected animals are a food safety concern. This computed prevalence can be used to assess quantitative microbial risk assessment models to further predict public health burden.

The primary purpose of this 4-year interdisciplinary multi-Hispanic Serving Institutions (HIS) project to **Texas A&M University-Corpus Christi** is to increase the number of south Texas students graduating from 2-year associate degree-granting institutions (Del Mar College and Texas State Technical College) transitioning to 4-year bachelor of science and masters of science degrees (Texas A&M Corpus Christi, Texas A&M Kingsville, and the University of Texas Rio Grande Valley) in fields related to the agricultural, plant and biological sciences. Faculty and staff at partner institutions will provide undergraduate and graduate training and education in the use of Unmanned Aerial Systems (UAS) technology for precision farming in agriculture. Targeted coursework will be created to include two permanent online introductory courses in UAV technology and ethics and one blended (online/hands-on) course in UAS applications. Training will include internships and assistance in research projects aligned with UAS as a tool for crop/soil management, and plant and natural resource sciences. Products will produce 28 bachelor of science and 11 masters of science graduates working in food, agriculture, and

natural resources related fields. This project will also affect 48 students from 2-year academic institutions. Educational needs areas addressed by this project include: (1) curricula design in terms of development of new courses of study and (5) student experiential learning. The major project outcome will be to provide approximately 40 Hispanic Americans with additional experience and education in food, agricultural, and natural sciences to be better prepared to engage in careers with the USDA or other Federal agencies as well as the private sector. This will ultimately increase diversity of the national workforce.

**The Native Waters on Arid Lands (NWAL)** project was funded by the USDA-NIFA AFRI Water for Agriculture Challenge Area as a Coordinated Agricultural Project at \$4.5 million over 5 years. The NWAL Annual Tribal Summit is a key outreach component of NWAL, designed to integrate tribal perspectives and insight into NWAL research, outreach, and education activities. In November 2015, the NWAL team planned, organized, implemented, and evaluated the first of five annual summits. The 2015 NWAL Summit included a *Native American Farm Managers Panel* with representation from three of the largest Native American Farms in Arizona. Technical sessions included: (1) Irrigation and Water Infrastructure; (2) Traditional Knowledge; (3) Climate Adaptation; and (4) Tribal Agriculture Economics. Keynote presentations encompassed Climate Change, Tribal Water Rights, Tribal Land Tenure, and Tribal College and University (TCU) Water/Hydrology Programs. Participants rated the summit highly (4.0-4.5 out of available scores of 1-5) with regard to providing the opportunity to: (1) meet people who will be useful in future work; (2) have tribal communities to exchange information and ideas about agriculture and water resiliency; (3) better understand traditional knowledge as it applies to tribal climate adaptation; (4) learn about what makes other tribes vulnerable to climate change; and (5) have a better understanding of the impacts of climate change on tribal lands and tribal water resources. The survey results also contained a recommendation for the NWAL Team to engage more youth and

students in related research and education. NWAL team members have developed and published the project website (<http://nativewaters-aridlands.com>), the research and outreach program plan, and gathered primary and secondary data needs from all NWAL team members to develop, plan and schedule activities in future years. The team developed a 5-year work plan and updated the NWAL Logic Model indicators and evaluation methods and instruments. The team established criteria to characterize tribal reservations involved in agriculture in the American Southwest and collected/analyzed data pertaining to contemporary agricultural production, traditional agricultural practices, and data related to land base and tribal water rights, income, employment, and demographics. This information was used by the team to discuss and prioritize tribal communities that will be engaged in more extensive research with the NIFA-funded project, including the Hopi, Navajo, Colorado River, Gila River, Zuni, Ouray/Uintah, Duck Valley, Pyramid Lake, and Walker Lake tribes.

Food security is best served by a national infrastructure of private and public professionals who routinely monitor crop health and pest incidence then translate this knowledge to a shared platform enabling rapid dissemination of mitigation measures to limit crop loss. **The Integrated Pest Information Platform for Extension and Education (iPiPE)** provides such an infrastructure with cyber-age tools, information products, and expert commentary for detection and management of new, foreign, or emerging target pests and endemic pests that threaten U.S. crops. By categorizing pests, data, and users, it enables sharing observations while protecting privacy of individuals, companies, and government agencies. The 28 iPiPE Crop-Pest Programs will incentivize growers and consultants to submit observations on target and endemic pests by providing tools and information for timely management decisionmaking. Coordinated by extension professionals from across the Nation, programs address a variety of crops and pests and provide undergraduate students (56-112) with hands-on extension and diagnostic experiences. Risk-based research will prioritize detection efforts for target

pests and direct in-field scouting for endemic pests. Twenty disease infection and pest phenology models were developed in 2016 and run operationally on the iPiPE platform: (i) Apples (two spotted mite, spotted tentiform leaf miner); (ii) Corn (Northern corn leaf blight, corn stalk borer, Southern rust, Boll worm bud worm complex, and Goss' wilt); (iii) Soybean (Wisconsin Soybean *Sclerotinia* model, Soybean frogeye leaf spot, and soybean *rhizoctonia*); (iv) Alfalfa (two spotted mite); (v) Vegetables (carrot bacterial blight, early blight, late blight); and (vi) wheat (wheat spot blotch, *Stagnospora nodorum*, Stripe rust, leaf rust, *Septoria* leaf spot, wheat powdery mildew).

Researchers at **Rutgers University and Oregon State University** have made great strides in understanding the inheritance of eastern filbert blight resistance (EFB) in hazelnuts. EFB, a stem canker disease found only in North America, is devastating to the European hazelnut and threatens the sustainability of current commercial production in the Willamette Valley of Oregon, where 99 percent of the U.S. crop is grown. They have identified new sources of resistance from Russia, Crimea, Turkey, and the Republic of Georgia. They have examined progenies from many sources of resistance, confirmed the presence of heritable resistance, and documented inheritance patterns. Further, they used molecular tools to place R-genes on the hazelnut genetic linkage map, which helps scientists know more about the diversity of genes present and will allow breeders to cross parents with known R-genes to pyramid genes in their progeny. In addition, they have fingerprinted over 700 accessions and will complete a comprehensive diversity study from these data making the USDA *Corylus* collection one of the best characterized in the National Plant Germplasm System. Most importantly, they are applying the knowledge generated through this project to breeding efforts in Oregon and New Jersey where it is guiding breeding decisions to meet the goals of securing and enhancing widely adapted, sustainable hazelnut production.

Roughly 800,000 tons of poultry litter are generated yearly by approximately 600 million broiler chickens, and most of this litter is applied to the surface of no-till soils, where nitrogen readily volatilizes as ammonia and phosphorus (P) washes off to surface water bodies, causing significant odor emissions to occur. For the past 2 years, researchers at the **University of Maryland, Eastern Shore** have worked with the first generation of a USDA-ARS technology to test the feasibility of subsurface application of dry poultry litter to soils on Delmarva, pioneering its introduction to the Chesapeake Bay watershed. This technology can significantly lessen the environmental impacts of poultry litter application while increasing crop yields due to better nutrient-use efficiency. This project seeks to refine this technology and transfer it to local farmers by improving its design so it will not cause increased leaching losses of P under certain soil conditions. Thus, this project represents the highest priority to local agricultural and environmental concerns, as it offers an alternative to surface application of litter to no-till soils with minimum tillage and without exacerbating other environmental concerns.

U.S. farmers have relied on increasing productivity through adoption of the latest research technologies and advances to remain competitive. Large agri-business corporations rely on internal research and development to improve economic performance. However, small and limited-resource farmers depend on land-grant universities. Universities have begun to encourage researchers to protect technologies through patents to generate revenue. This trend is leaving small and limited-resource farmers farther and farther behind. The challenge for land-grant universities is to seek new ways to respond effectively and more rapidly to clientele needs. But with shrinking budgets, they need to find more innovative, less expensive, and more rapid extension methodologies. The **University of Arkansas, Pine Bluff** has improved its ability to respond to clientele needs by integrating research and development with technology transfer in a compressed timeframe. This innovative, new extension model will then be presented at regional, national, and international professional meetings to extend the concept and

methodology to extension professionals elsewhere. The proposed approach is to test a new extension model based on the design-build approach in use by engineers. This project will involve closely coordinated partnerships with research and extension personnel and fish farmers. Extensive coordination and communication will be needed in real time to integrate the expertise and insights of the engineers, aquaculture specialists, and economists involved in this process. This new extension approach will build upon the platform of the well-established research verification method of technology transfer. Research verification is a specialized form of a result demonstration. In research verification, a team of research and extension experts develop a specialized protocol for production that is based on the best available science. Research verification has been shown to reduce the time from development of a new technology to its adoption. Research verification programs frequently demonstrate the higher yields and lower costs that can be attained by closely following recommendations from the latest research results.

**Central State University** faculty, undergraduate students, and industry partners will enhance crop production efficiency with reduced environmental impact by replacing post-emergence herbicide use with directed energy to control weeds that compete with the crop for nutrients, water, and light. Their solution spot-illuminates unwanted plants (weeds) with predetermined light frequencies at certain intensities and duration, controlled by integrated sensors and robotics. There is no equivalent non-chemical commercial farm product in the United States available today. Recently funded research has demonstrated in non-agriculture situations the ability to manage, prevent, and abate unwanted plants in areas that require control. This approach has been shown effective to both remove unwanted plants and to keep seeds from germinating. Complete control was observed under greenhouse test conditions, including leaf chlorophyll loss, leaf desiccation, bark damage, biomass loss and no re-greening or re-growth. Attempts to apply this emerging directed energy plant disrupter platform to agriculture has been well received and shown early promise. It will impact student preparation for careers that intersect plant

sciences, environmental stewardship, precision agriculture technology development and insertion, organics, and sustainable agriculture practices.

### 11.7 Outreach Activities

- On March 29, 2016, the SBIR program and the USDA Office of Technology Transfer presented a webinar titled “Partnership Pays: Building a Research Partnership with U.S. Department of Agriculture (USDA) Agricultural Research Service to Enhance Your USDA SBIR Proposal” in an effort to encourage more small business firms to enter into CRADA agreements with ARS prior to submitting proposals to the SBIR program. Results of this webinar indicated an increase in small businesses contacting ARS to explore CRADA or licensing opportunities in preparation for USDA SBIR Phase I application.
- A number of NIFA’s National Program Leaders attended National SBIR Conferences in Washington, DC, and Austin, TX, with formal presentations on the USDA SBIR program which included information about the Office of Technology Transfer. Additionally, the USDA SBIR program staff conducted one-on-one meetings with over 25 small business entrepreneurs at each conference and discussed opportunities for both SBIR and Office of Technology Transfer. In addition, the USDA SBIR program participated in webinars for Arizona, Arkansas, and Southern California.
- In FY 2016, the USDA SBIR program staff participated in conjunction with the SBA in three SBIR Road Tours and also attended four regional SBIR conferences, including two SBIR National Conferences, and conducted outreach to potential small businesses found in

underrepresented States. In each case, a presentation was provided on the USDA SBIR program and included information and opportunities for the Office of Technology Transfer. The road tours provided outreach to approximately 1,600 attendees in total, provided on average 20-30 one-on-one meetings with small business entrepreneurs at each meeting, and covered the following States AR, GA, IA, IN, KS, MO, ND, NE, OK, SC, SD, TN and WY. In FY 2017, the USDA SBIR program will participate in National SBIR Conferences in Washington DC, and Austin, TX, three SBA Road Tours, and four regional meetings, primarily in rural States.