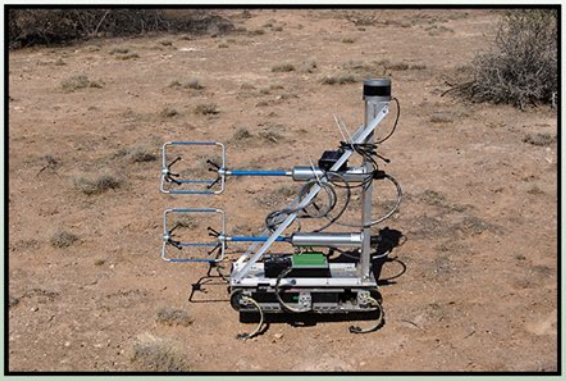
United States
Department of
Agriculture

Agricultural Research Service's
FY 2019 Annual Report on Technology Transfer



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3.0 Agricultural Research Service (ARS)

3.1. Mission Statement

ARS delivers scientific solutions to national and global agricultural challenges.

3.2. Nature and Structure of Research Program

ARS is the largest intramural scientific research agency of the U.S. Department of Agriculture (USDA). 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) 2019, ARS employed approximately 2,000 scientists and postdoctoral researchers, and approximately 6,000 other employees to conduct 690 research projects at more than 90 locations. Research projects were organized within 1 of 16 national programs (see table). The Office of National Programs (ONP) in Beltsville, Maryland, plans the scope and objectives of the Agency's research projects, and five area directors implement research projects at the locations in their geographic areas.

ARS research program management, showing 16 national programs

Animal Production and Protection	Natural Resources and Sustainable Agricultural Systems	Crop Production and Protection	Nutrition, Food Safety, and Quality
Food Animal Production	Water Availability and Watershed Management	Plant Genetic Resources, Genomics and Genetic Improvement	Human Nutrition
Animal Health	Soil and Air	Crop Production	Food Safety (animal and plant products)
Veterinary, Medical, and Urban Entomology	Grass, Forage, and Rangeland Agroecosystems	Plant Diseases	Quality and Utilization of Agricultural Products
Aquaculture	Biorefining	Crop Protection and Quarantine	
	Sustainable Agricultural Systems Research		

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 active research project undergo a thorough, independent external prospective peer review managed by the Office of Scientific Quality Review. 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 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, the 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 USDA 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 on IP matters 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. Area office technology transfer staff members 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 Partnership and Administration Section conducts day-to-day operations, coordinates technology transfer policy development, interacts with ONP 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, managing, and reviewing agreements, and overseeing and managing the Agricultural Research Partnerships (ARP) Network. The Patent Section of OTT 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), and a Plant Protection Committee; preparing and prosecuting patent applications; and reviewing patent legal work performed by a cooperator and an ARS contract law firm. The Licensing Section of OTT manages invention licensing from all the intramural scientists in every USDA agency, including the review of license applications, negotiation of licenses, and monitoring of license agreements to assure compliance. This section also collects and disburses

license revenues, manages international patent filings, and provides expert advice on all matters related to USDA invention licensing.

At ARS, 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 Protection certificates, and biological materials); and
- Participating in meetings with industry organizations and universities; workshops and field days; and distributing information to the public via the ARS Office of Communications, 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 incentivize commercialization and to facilitate technology transfer to the marketplace. This is usually the case when complementary investment by the private sector is necessary to commercialize a product and patent protection is required to protect this investment. 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. 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. In licensing practices, ARS continues to reserve the right to allow use of any IP-protected

technology for research purposes (non-commercial).

Meaningful performance metrics in technology transfer are often difficult to formulate. ARS has defined better metrics for technology transfer within USDA. For example, successful outcomes for ARS may include improved agricultural practices, gathering and compilation of 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 that can capitalize on the ARS research capacities, facilities, and research outcomes.

Licensing policies also promote small business success with reasonable licensing fees in the early years and 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 higher than the 15 percent required by statute). Thus, policies are in place that incentivize commercialization, minimize transaction costs, and provide fair and equitable compensation for those who create Federal innovations.

OTT founded the ARP Network to expand the impact of ARS research by enhancing the likelihood that these outcomes will be 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 ARP 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.

3.4. Technology Transfer Highlights

- In FY 2019, there were 193 active CRADAs, 56 of which were newly executed. The 56 new CRADAs contributed $3,280,189 directly to ARS research projects, and approximately 68 percent of them are with small businesses. There were 292 active Material Transfer Research Agreements (MTRAs), 100 of which were newly executed. The 100 new MTRAs contributed $637,636 directly to ARS research projects (see Table 1 in Section 3.5 and Figures 1 and 2 in Section 3.9).

- In FY 2019, 228 new invention disclosures were received; 85 patent applications were filed; and 65 utility patents, 8 plant patents, and 3 Plant Variety Protection Certificates were obtained. Although the year in which a patent is issued is not typically the year in which the patent application is filed, over time the ratio of patents issued over the number of patent applications filed is an indicator of "judicious" patenting. Over the last 5 years, this indicator suggests that approximately 66 percent of the patent applications result in an issued patent (see Table 2 in Section 3.5 and Figures 3, 4, and 5 in Section 3.9).

- In FY 2019, 51 new licenses were executed (49 percent with small businesses and 20 percent with universities). The total number of active licenses has steadily increased over the last 5 years from 404 to 497. Sixty-three percent of the income-bearing licenses were granted exclusively.

The total income from all active licenses was more than $3.55 million. Most of the income in FY 2019 came from a few licenses; the median earned royalty income was $3,154. Although the year that a license is signed is not typically the year the patent is issued, over time the ratio of newly signed licenses over the number of newly issued patents is an indicator of "judicious" patenting, considering the commercial viability of the technology and other factors. Over the last 3 years, this indicator suggests that approximately 40 percent of the issued patents have been licensed (see Tables 3, 4, and 5 in Section 3.5 and Figures 6, 7, 8, and 9 in Section 3.9).

- OTT reviewed and executed licenses for the Animal and Plant Health Inspection Service (APHIS) and U.S. Forest Service.

- OTT employees served as moderators/speakers/trainers in broad technology transfer activities and forums, including the Federal Laboratory Consortium national and regional meetings; National Summit on Rural Entrepreneurship; and National Association for Community College Entrepreneurship annual meeting.

- OTT held in-person technology transfer training with 283 scientists at 15 locations in 10 States.

- OTT received 106 Innovation Fund applications of which 36 were funded. The Innovation Fund provides ARS scientists up to $25,000 on a competitive basis for a given project per year. The purpose of the fund is move ARS research outcomes closer to adoption by industry, academia, and other stakeholders.

- OTT devised and enhanced a two-way communication mechanism between technology transfer professionals (both at OTT and area offices), ONP, and scientists in the field through the use of technology transfer strategy calls after each patent decision and each Innovation Fund round. In

FY 2019, 141 strategy sessions were conducted to devise customized technology transfer strategies to ensure adoption of research outcomes of each project. This was featured in the Best Practice Spotlight of *Technology Transfer Tactics*, a monthly newsletter, in March 2018.

- OTT created a LinkedIn group for the ARP Network. Through FY 2019, membership grew from 250 to nearly 500. In FY 2019, there were 35 LinkedIn posts by OTT. Posts include highlighting a research topic area with an overview of the past and present ARS research program in that area, followed by a posting of technologies available for licensing in that area. In addition, other noteworthy items are posted, such as ARS news, research partnership opportunities, USDA videos on various research projects, and Federal business resources. Most posts received more than 200 views.

- OTT created a quarterly electronic newsletter called "ARP Notes" to update ARP Network members on ARS and members' activities and events and inform members of ARS partnerships and/or licensing opportunities. ARP Notes are distributed by email to more than 150 individuals and through LinkedIn. On LinkedIn ARP Notes receive 300 to 400 views. ARS tweets an announcement of each new issue of ARP Notes.

- OTT developed new outreach materials that include:
    - ✓ Snapshot and narrative: a single-page handout with an easy-to-read synopsis of ARS technology transfer activities for the fiscal year.
    - ✓ OTT brochure: a trifold publication that describes the OTT office and its functions.
    - ✓ Trade booth: table-top and side-panel displays for use at outreach events.
    - ✓ OTT icons: icons for each section in OTT, as well as an icon for the office.

- ✓ Bookmarks: bookmarks describing eight technologies within the top 20 revenue generating licenses.
- ✓ Flipbook & brochure: a small flip book and brochure describing 17 technologies within the top 20 revenue generating licenses.

- OTT participated in two U.S. Small Business Administration (SBA), Small Business Innovation Research (SBIR) Road Shows. The road shows visited and held workshops in five cities in the U.S. Central Plains and five cities in the U.S. Northeast. During the workshops, OTT highlighted the USDA SBIR-Technology Transfer Program that encourages SBIR applicants to collaborate 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."
- OTT served on the Inter-Agency Working Group on Technology Transfer, led the Return on Investment Group on Private Sector Engagement, and represented USDA on the Lab to Market subcommittee of the National Science and Technology Council's Committee on Technology. OTT took the lead on the Metrics Strategic Group to establish meaningful ways in which to quantify the outcomes of Federal research and development enterprise.

- OTT participated in creating an improved LabTech in Your Life, a virtual environment where visitors can explore the familiar setting of a home and discover successfully commercialized Federal technologies that are now commonly used household items. ARS developed 17 technologies throughout the house. LabTech in Your Life is hosted on the Federal Laboratory Consortium website at https://www.federallabs.org/successes/labtech-in-your-life.

- OTT created and along with the ARS Office of International Research Programs led a 4-day technology transfer workshop held in Egypt to train Egyptian academic and technology transfer professionals. The workshop included U.S. speakers from USDA, the National Institutes of Health, the Department of Energy, University of Maryland, industry (MedImmune), and research institutes (Salk).

- OTT published a peer-reviewed paper, "To Protect or Not to Protect: Guide for Deciding on Public Release or IP Protection of New Plant Cultivars and Germplasm", in Volume 54 (4) of *HortScience*.

3.5. Metric Tables

TABLE 1. Collaborative relationships for research and development					
	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Total number of active CRADAs	223	219	249	189	193
Active CRADAs with small businesses	98	70	62	73	120
Total number of newly executed CRADAs	41	39	57	51	56
Newly executed CRADAs with small businesses	31	12	17	31	38
Total funds to be received	$2,250,129	$2,113,880	$2,804,160	$3,121,739	$3,280,189
Total number of active MTRAs[2]	199	288	432	354	292
Newly executed MTRAs	62	89	101	118	100
Total funds to be received	$358,654	$373,953	$743,603	$2,267,886[4]	$637,636
Total number of active other agreements[3]	2,899	3,230	4,108	3,215	1,888
Newly executed other agreements	687	756	876	621	951
Number of newly executed MTAs	743	823	664	645	614
Newly executed outgoing MTAs	513	539	445	476	398
Total number of publications[4]					
Peer-reviewed scientific journal	4,564	4,473	4,467	4,138	3,816
Trade journal	57	65	66	68	48
Meeting abstracts	1,347	1,178	1,022	855	612

[1] Material Transfer CRADAs.
[2] Material Transfer Research Agreements. Involves collaborative research on a specific material.
[3] Includes Trust Fund Cooperative Agreements, Reimbursable Agreements, Interagency Agreements, and Non-Funded Cooperative Agreements.
[4] Number of published manuscripts.

TABLE 2. Invention disclosures and patenting					
	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Total new invention disclosures[1]	175	174	169	306	228
University co-owned	40	58	27	29	39
Non-university co-owned	27	29	21	16	18
USDA solely owned	108	87	121	261	171
Scientific discipline:					
Biological materials	32	19	8	141	86
Life science	64	73	72	55	47
Chemical	48	48	43	32	42
Mechanical & measurement	18	21	28	20	13
Plant patents[2]	3	5	5	6	2
Plant variety protection[2]	10	8	13	11	4
Plant breeder's rights[2]	0	0	0	0	1
Plant public release	39	28	44	41	33
Based upon CRADA research	23	25	22	23	14
Total patent applications filed[3]	110	92	109	108	85
University co-owned	25	10	21	31	17
Non-university co-owned	26	9	23	25	17
USDA solely owned	59	73	65	52	51
U.S.	ND	ND	ND	ND	ND
Foreign	ND	ND	ND	ND	ND
Scientific discipline:					
Life science	47	50	45	53	29
Chemical	38	24	38	30	34
Mechanical & measurement	15	10	7	14	12
Plant patents	4	6	11	3	4
Plant variety protection	6	2	8	8	6
Total patents issued[3]	84	53	68	61	65
University co-owned	12	15	22	19	16
Non-university co-owned	20	12	19	11	21
USDA solely owned	52	26	27	31	28
U.S.	ND	ND	ND	ND	ND
Foreign	ND	ND	ND	ND	ND
Scientific discipline:					
Life science	33	23	37	29	33
Chemical	20	13	13	15	17
Mechanical & measurement	10	9	6	12	4
Plant patents	15	5	6	2	8
Plant variety protection	6	3	6	3	3

ND, data not available.
[1] Inventions arising at a Federal laboratory. For FY 2014, also includes the plants protected through Plant Variety Protection.

[2] In the United State, 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. International plants are protected through plant breeder's rights.
[3] 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.

TABLE 3. Profile of active licenses

	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Total active licenses[1]	404	419	426	460	497
Executed to small businesses[2]	147	150	155	161	180
Executed to start-up businesses[3]	12	6	6	6	6
Executed to universities	175	187	186	199	201
Amended in FY	5	4	4	8	4
Invention licenses[4]	339	348	351	374	377
Executed to small businesses	112	112	114	113	114
Executed to start-up businesses	12	6	6	6	6
Executed to universities	166	178	176	189	188
Other IP Licenses[5]	65	71	75	86	120
Executed to small business	35	38	41	48	66
Executed to start-up businesses	0	0	0	0	0
Executed to universities	9	9	10	10	13
Total newly executed licenses	35	29	38	40	51
Executed to small businesses	16	9	19	12	25
Executed to start-up businesses	0	0	0	0	0
Executed to universities	9	14	9	12	10
Invention licenses	20	23	29	27	17
Executed to small businesses	5	6	13	3	7
Executed to start-up businesses	0	0	0	0	0
Executed to universities	8	14	8	12	7
Other IP Licenses	15	6	9	13	34
Executed to small businesses	11	3	6	9	18
Executed to start-up businesses	0	0	0	0	0
Executed to universities	1	0	1	0	3

ND, data not available.
[1] The rest of the licenses were to medium or large size businesses.
[2] A small business, together with its affiliates, must not have more than 500 employees.
[3] 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.
[4] Invention licenses refer to patents and Plant Variety Protection certifications.
[5] Other IP licenses refer to biological materials licenses.

TABLE 4. Characteristics of income-bearing licenses					
	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Total income-bearing licenses	402	418	425	459	496
Exclusive	274	289	293	312	312
Partially exclusive	11	9	6	7	7
Non-exclusive	117	120	126	140	177
Invention licenses[1]	337	347	350	373	376
Exclusive	266	280	283	302	299
Partially exclusive	11	9	6	7	7
Non-exclusive	60	58	61	64	70
Other IP licenses[2]	65	71	75	86	120
Exclusive	8	9	10	10	13
Partially exclusive	0	0	0	0	0
Non-exclusive	57	62	65	76	107
Total royalty-bearing licenses	139	145	129	134	125
Invention licenses	121	123	107	112	105
Other IP licenses	18	22	22	22	20

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

TABLE 5. Income from licensing					
	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Total income all active licenses	$5,066,988	$4,784,466	$5,713,803	$3,799,170[5]	$3,553,446
Invention licenses[2]	$4,842,256	$4,456,054	$5,377,909	$3,490,236	$3,272,205
Other IP licenses[3]	$224,732	$328,412	$325,566	$308,934	$281,241
Total Earned royalty income (ERI)	$3,509,904	$3,633,239	$3,503,866	$2,715,861	$3,171,355
Median ERI	$3,525	$3,966	$3,698	$3,056	$3,154
Minimum ERI	$13	$5	$15	$21	$ 0.75
Maximum ERI	$728,017	$818,537	$769,167	$265,844	$573,545
ERI from top 1% of licenses[4]	NP	NP	NP	NP	NP
ERI from top 5% of licenses	$1,756,460	$1,811,637	$1,639,557	$1,218,975	$1,579,185
ERI from top 20% of licenses	$2,856,924	$3,043,395	$2,933,342	$2,227,058	$2,655,368
ERI distributed					
Inventors	$1,632,130	$1,188,389	$2,443,702	$1,322,224	$1,244,190
Funds used for salaries[5]	$2,819,906	$2,051,317	$1,449,005	$1,461,164	$1,145,432
Innovation Fund[5]	ND	ND	$483,814	$618,000	$833,500
Patent filing preparation, fees, & annuity payments paid	$621,701	$393,533	$576,120	$423,948	$567,423

ND, data not available; NP, data not presented; ERI, earned royalty income.
[1] Two of the top revenue-generating licenses expired in FY 2017.
[2] Invention licenses refer to patents and Plant Variety Protection certifications.
[3] Other IP licenses. Refer to biological materials licenses.
[4] Not presented, represents one license.
[5] Funds were from FY 2017 revenue.

TABLE 6. Licensing management: elapsed execution time and termination					
Agricultural Research Service	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
All licenses					
Average (months)	2.8	4.9	6.1	6.3	5.9
Median (months)	2.5	3.7	5.1	5.5	5.0
Minimum (months)	0.5	0.9	1.3	0.9	1.8
Maximum (months)	10.0	16.0	13.7	24.1	34.9
Licenses terminated for cause	0	0	0	0	0

3.6. Downstream Outcomes

NUTRITION, FOOD SAFETY, AND QUALITY

National Programs:

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

A healthy microbiome in infants predicts better vaccine response.

Vaccination is the best approach to prevent infectious diseases, but response to vaccines can be highly variable for unknown reasons, especially when given in early infancy. ARS scientists in Davis, California, conducted a study of 306 infants aged birth to 3 years to determine whether an infant that had a microbiome colonized with greater numbers of a beneficial bacteria (*Bifidobacterium infantis)* had better responses to four vaccines (tuberculosis, polio, hepatitis B, and tetanus) also given in early infancy. The abundance of *Bifidobacterium* was positively associated with better responses to the tuberculosis, tetanus, and hepatitis B vaccines when the responses were measured in early infancy and was also associated with better responses to the tuberculosis, tetanus, and polio vaccines measured at 2 to 3 years of age. This study is the first to demonstrate that *Bifidobacteria*, which are abundant in the

infant gut as a result of breastfeeding, may lead to long-term enhancement of the immune system. This observation demonstrates that early life nutrition can improve health by enhancing vaccine memory responses. (NP 107, Project No. 2032-51530-026-00D)

Newly created atlas of epigenetic variation in humans.

More than 15 years after scientists first mapped the human genome, most diseases still cannot be predicted based on genes, leading researchers to explore epigenetics as causes of disease. The most stable form of epigenetic regulation is DNA methylation, which changes gene conformation and gene expression, but progress on this topic has been limited by lack of information on cell type specificity. ARS-supported scientists in Houston, Texas, performed deep sequencing of genomic DNA in tissues representing the three germ layers during development followed by producing a computer algorithm to identify individual regions that vary in DNA methylation. The nearly 10,000 regions the researchers mapped out, called correlated regions of systemic interindividual variation (CoRSIVs), comprise a previously unrecognized level of molecular individuality in humans. Because epigenetic marking of genes has the power to either stably silence or activate them, any disease that has a genetic basis may also have an epigenetic component. This map forms the basis of understanding about disease processes from an epigenetic perspective. (NP 107, Project No. 3092-51000-059-00D)

Improving USDA food composition databases.

USDA food composition databases are used by a diverse community to make policy decisions, investigate the impact of diet on health, develop new foods, advise patients on improving their diets, and address the general need for more information on what is in the food we eat. The USDA has been compiling data on food composition for more than 100 years, but in recent years the amount, type, and format of the data have become outdated. To rectify this problem ARS scientists in Beltsville, Maryland,

created and publicly released FoodData Central. FoodData Central provides access to all USDA food composition information—such as expanded nutrient information, links to Special Interest Databases, and links to related agricultural and experimental research data—in a single location. The USDA databases includes legacy databases, a database used for the What We Eat in America survey, data on branded food products, and Foundation Foods (the primary source of analytical food composition data from this point forward). This new database will allow the USDA to continue to be the world's foremost authority for nutritional data well into this century. (NP 107, Project No. 8040-52000-064-00D)

Intermittent feeding promotes growth more than continuous feeding in a neonatal pig model.

Every year, more than 50,000 infants born prematurely in the United States cannot eat normally and may be fed by a tube inserted into the stomach. Preemies may be fed continuously or intermittently as if one were consuming meals. So far, it is unknown whether there is a benefit of one pattern of feeding. A comparison cannot be performed in infants for ethical reasons, so to study this question under controlled conditions, ARS-supported scientists in Houston, Texas, studied neonatal pigs with implanted stomach tubes for 21 days. Even though both groups were fed the same amount of nutrients, body weight, lean mass, spine length, and muscle mass were all greater in the piglets fed intermittently. Additional results from this study suggest the pulsatile changes in amino acids and insulin contributed to the benefits. Widespread adoption of pulsatile feeding of premature infants has the potential to improve growth, reduce the length of hospital stays, and lower health care costs. (NP 107, Project No. 3092-51000-065-00D.

***Escherichia coli* O157:H7 transmission by cattle pest flies found in leafy greens.**

Leafy greens are a leading source of *E. coli* O157:H7 bacteria that cause human foodborne illness. Pest flies can carry this pathogen and may transmit it to leafy greens and other fresh produce. ARS scientists

in Clay Center, Nebraska, determined the occurrence of E. coli O157:H7-positive flies in leafy greens planted up to 600 feet from a cattle feedlot, and assessed their potential risk for transmitting this pathogen to leafy greens. *E. coli* O157:H7 carriage rates of house, face, flesh, and blow flies were similar to each other and were greater than the carriage rate of stable flies. *E. coli* O157:H7 carriage rates were not different in flies found at different distances from the feedlot, ranging from 0 to 600 feet. Genetic subtyping showed that the majority of the *E. coli* O157:H7 found in the flies were of the same predominant subtypes found in the feedlot pen surface manure and the leafy greens, indicating the potential role for flies to transmit *E. coli* O157:H7 to the leafy greens. Due in part to this work and previous research, the produce industry has revised its guidelines for growers to increase the set-back distance between leafy greens fields and concentrated animal feeding operations. This information is critical for understanding the food safety risks associated with growing leafy greens in close proximity to cattle production, for determining safe distances between cattle feedlots and fresh produce that will reduce preharvest contamination and protect public health, and as potential guidance under the Produce Safety Rule as part of the Food and Drug Administration's Food Safety Modernization Act. (NP 108, Project No. 3040-32000-032-00D)

Development of hot-fill pasteurization of cucumber pickle spears as an alternative to tunnel pasteurization.

For commercial production of acidified vegetable products, a tunnel pasteurizer is typically used for thermal processes. To help reduce energy costs and water use, ARS researchers in Raleigh, North Carolina, developed a hot-fill method for pasteurizing cucumber pickle spears in 24-ounce pickle jars. The method required refilling jars multiple times with a hot brine (around 175°F). The data showed that for cucumber spears a hot-fill method could achieve or exceed temperatures typically used for commercial pasteurization of pickle by most manufacturers. These conditions exceed published values

needed for the required reduction of bacterial pathogens in acid and acidified vegetable products; they were also sufficient to meet Food and Drug Administration regulations and typical industry processing conditions needed for good quality texture and sensory properties. Although further development of processing equipment may be needed for inverting and refilling jars, the in-jar pasteurization process has potential application for cucumber spears and related products and may be used to save on the water usage and costs of currently used tunnel pasteurizers. (NP 108, Project No. 6070-41420-008-00D)

Location, season, and manure type affect pathogen survival in manure-amended soils.

The Produce Safety Rule, part of the Food and Drug Administration's Food Safety Modernization Act, states that untreated manure must be applied 90 or 120 days prior to the harvest of edible produce crops to minimize contamination from pathogens that may be present in untreated manure. However, this interval was not scientifically validated. Over 12 separate field trials conducted in mid-Atlantic States over 4 years, ARS researchers in Beltsville, Maryland, and university collaborator showed that spatiotemporal factors (site, year, and season) affect survival durations of *Escherichia coli* in manure-amended soils more than agricultural factors (manure type, organic or conventional management of soils, and depth of application) or weather effects. The results provide critical information to growers on the potential risk of produce contamination with specific raw animal manure application. The Food and Drug Administration will use these data to develop food safety standards for controlling bacterial contamination of fresh produce from soil. (NP 108, Project No. 8042-32420-006-00D)

Development of novel antibodies and detection assay to screen food samples for colistin-resistant bacteria.

The recent discovery and rapid spread of the mobile colistin-resistant gene MCR-1 in bacteria is undermining our ability to treat bacterial infections and threatening human health and safety. ARS

researchers in Albany, California, developed novel polyclonal and monoclonal antibodies against MCR-1 and MCR-2. An enzyme-linked immunosorbent assay using these antibodies was able to detect 0.01 ng/mL of MCR-1 in buffer and 0.4 colony-forming units per gram of meat, including ground chicken, pork, and beef, demonstrating strong tolerance to complex food matrices. This immunoassay could be used for rapid and reliable screening of food samples contaminated with colistin-resistant bacteria, making this an important tool for reducing the risk of foodborne infections with antibiotic-resistant bacteria. (NP 108, Project No. 2030-42000-049-00D)

Neutralization of residual antimicrobial processing chemicals in broiler carcass rinse.

The USDA's Food Safety and Inspection Service (FSIS) has established pathogen reduction performance standards for Campylobacter, a poultry associated-bacterial pathogen of significant concern both nationally and internationally, on broiler carcasses. Processors may apply antimicrobial processing aids as a spray or immersion to lower contamination on carcasses. In the United States, broiler carcasses are generally sampled by whole carcass rinse, and the potential exists for residual levels of antimicrobial processing aids to be carried over into the rinsate. It has been previously shown that, if unmitigated, such carryover can interfere with the detection of Salmonella. ARS researchers in Athens, Georgia, further demonstrated that unmitigated carryover of antimicrobial treatment can also interfere with the detection and recovery of Campylobacter in broiler carcass rinse samples. Traditional buffered peptone water was tested and found that it did not offer enough neutralizing capability to counteract residual antimicrobial activity of some post-chill processing aids (peroxyacetic acid, cetylpyridinium chloride, acidified sodium chloride, or a blend of acids) to allow full recovery of Campylobacter. A recently reported formulation for a neutralizing buffered peptone water, developed by ARS in Athens, Georgia, and currently being used by FSIS, outperformed the traditional carcass rinse medium and allowed significantly improved recovery of Campylobacter even in the presence of three of the four tested

antimicrobial processing aids. Performance of the new carcass rinse medium with the fourth antimicrobial processing aid (acidified sodium chloride) was not different from the traditional formulation. Neutralizing buffered peptone water represents a significant improvement in the broiler carcass rinse method for detecting Campylobacter. (NP 108, Project No. 6040-32000-009-00D)

New freezing technology retains fresh-like fruit quality when thawed.

Freezing is a well-established technology used to prolong seasonal fruit and vegetable shelf-life. However, current freezing technologies (both slow and fast) rupture cells, resulting in juice loss when thawed, which leads to suboptimal flavor, juice content, and texture qualities. Together with colleagues at the University of California–Berkeley, ARS scientists in Albany, California, investigated a technology first developed to preserve human organs for transplanting called isochoric (constant-volume) freezing to extend the shelf life of food products and maintain their physical and nutritional properties. The researchers evaluated isochoric freezing to preserve the quality of sweet cherries and found the technology resulted in thawed fruit that were indistinguishable from fresh cherries in terms of juice loss, texture, structure, ascorbic acid content, and antioxidant activity. The isochoric method also uses 70 percent less energy compared with conventional freezing methods. These findings promise to transform the $54 billion U.S. frozen foods market by enabling frozen products that are thawed to have extended shelf-life and fresh-like taste, texture, juiciness, and nutrition. (NP 306, Project No. 2030-41000-064-00D)

A fresh fruit and vegetable cleaning system that prevents bacterial survival.

In current commercial fresh fruit and vegetable processing plants, the accumulation of organic materials in washing tanks allows for unhealthy bacterial survival as chlorine in the water is depleted. ARS scientists in Beltsville, Maryland, invented a novel “in-flight” non-soaking cleaning system that removes

organic material early in the process without damaging the fresh produce. This new process cleans all produce surface areas and effectively removes organic matter from cut surfaces while improving processing control and efficacy, thereby allowing produce to be stored longer without bacterial decay and reducing food waste. This system uses a combination of sanitizers and a consistent concentration of chlorine that removes bacterial contamination while eliminating toxic chlorine byproduct formation found in dechlorinating washing-tank systems. This in-flight system, which has a relatively small footprint, also allows for exceptionally efficient use of space in processing plants. Working with Church Brothers Fruit Company, ARS is scaling up this technology for commercialization. (NP 306, Project No. 8042-43440-005-00D)

Fast, accurate method to detect off-flavors in farm-raised catfish.

Off-flavor in farm-raised catfish is a major quality issue, particularly in late summer and early fall. Although professional flavor checkers check samples from production ponds before harvest, off-flavored fish are found in the market place. Commercial instruments that measure off-flavor compounds are available, but their use is expensive, time-consuming, and requires highly skilled technicians. ARS scientists in New Orleans, Louisiana, developed an analytical "pass/fail" method that reduces sampling time from 10 minutes to 1 minute, does not require skilled training, and has the sensitivity of human flavor checkers. Although this new analytical method is not intended to replace the human checkers, it will allow rapid checking of large numbers of samples. Harvest Select, Simmon's Catfish, and other processing plants in the Mississippi Delta region are testing this method for its accuracy and to determine the proportion of off-flavor fish reaching the market from each plant after its use. This information will be supplied back to the plants with the direct benefit of reducing the proportion of off-flavored fish reaching the consumer. (NP 306, Project No. 6054-44000-078-00D)

Development of a new, automated apple in-field sorting machine.

Automated in-field sorting enables low-quality or inferior fruit to be separated from fresh-market, higher-quality fruit at harvest, which allows for better efficiency and control during postharvest apple storage and packing and reduces overall food loss. ARS scientists at East Lansing, Michigan, designed and constructed a new, automated in-field apple sorting system. This simple system is compact, reliable, and capable of sorting 11 or more apples per second. Laboratory tests achieved 100 percent sorting accuracy with superior grading repeatability along with no bruising damage to fruit. This infield sorting system is being tested at Schwallier's Country Basket, a commercial orchard, and has been incorporated into the ARS-developed and commercialized self-propelled apple harvester. U.S. apple growers adopting this new in-field sorting technology can achieve significant cost savings in postharvest handling of harvested fruit, improve postharvest management, and reduce postharvest fruit loss. (NP 306, Project No. 5050-43640-002-00D)

A new, food-grade corn starch mixture stabilizes appealing foods.

There is a need for improved food-grade emulsifiers that do not have limits on their use. ARS scientists in Peoria, Illinois, developed an economical food-grade emulsifier that consists of high amylose corn starch and fatty acid salts from vegetable oil. When these two materials are processed using an industry standard technique, it forms an amylose inclusion mixture. This emulsifier has great value in salad dressing, ice cream, sodas, baked goods, and other products. This new low-cost and U.S.-made food-grade starch mixture can replace expensive imported emulsifiers or petroleum-based emulsifiers that have limits on their usage. This amylose-based emulsifier will result in new applications for corn starch benefiting U.S. corn producers, processors, and consumers. (NP 306, Project No. 5010-41000-166-00D)

Almond hulls: A waste product with high-value uses.

Almond hulls can be a viable source of industrial sugars because they contain more free extractable sugar than sugarbeets; however, once the sugars are extracted, uses must be found for the remaining biomass of spent hulls. ARS scientist in Albany, California, developed a novel application for spent hulls by using them instead of nonsustainable peat moss to commercially produce mushrooms. Propagating vegetative mycelium from mushrooms generally requires a specific peat moss mix (called casing) with uniform pore distribution for gas exchange, balanced minerals, and high water-holding capacity. Spent almond hulls possess these key traits; they have a water-holding capacity of greater than 500 percent, numerous pores in the size range optimal for gas exchange, and high mineral content ideal for mushroom growth. ARS researchers and collaborators at the California Almond Board, are now exploring the use of spent almond hulls as casing in commercial mushroom production at an industrial scale. (NP 306, Project No. 2030-41000-054-00D)

ANIMAL PRODUCTION AND PROTECTION

National Programs:

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

Application of an interspecies cross to improve the efficiency of genome sequencing and assembly. A new method for assembling genetic sequencing data into more complete genomes has been pioneered by ARS researchers in Clay Center, Nebraska, and Beltsville, Maryland, and collaborators at the National Institutes of Health, University of Nebraska, and University of Kentucky. Using the new process, an individual animal resulting from the mating of a Highland breed bull and a yak cow was used to create reference-quality assemblies of the Highland breed of cattle and the yak in a single experiment. By applying the new technique to an interspecies hybrid that maximized the differences between maternal and paternal chromosome sequences, the researchers created individual sequences for both the yak and cattle. The sequences were of equal or better quality than any existing mammalian genome assembly, including those for humans or biomedical species such as mice or rats. If generally applied, the technique to generate two genome sequences from a single individual is likely to improve

the accuracy of genomic selection of all livestock and many plant species and could impact a wide range of industries. (NP 101, Project No. 3040-31000-100-00D)

Development of a model to predict illness using swine feeding behavior.

Livestock feeding behavior is dependent on many factors, and feeding is a good proxy for assessing an animal's health because as an animal gets sick, feed consumption often drops off even before diagnostic symptoms such as fever or difficulty breathing appear. ARS scientists in Clay Center, Nebraska, and South Dakota State University collaborators used an electronic system to monitor the feeding behavior of pigs during the grow-finishing phase and applied machine learning tools to predict swine feeding behavior based on temperature and time of day. Large deviations between predicted and observed feeding behavior before a pneumonia outbreak demonstrated the potential for the model to be used in the automated early detection of a disease outbreak and other stressful events. This work will be used to develop a computer-based modeling system for swine feeding behavior. Future work is expected to lead to the development of software that will allow swine producers to use real-time feeding behavior data as an early predictor of illness and stress events in individual animals, thereby improving both animal well-being and productivity. This is an excellent example of the potential benefits of continuous monitoring of livestock for beneficial outcomes in animal health and production. (NP 101, Project No. 3040-31000-097-00D)

Characterization of the porcine mycobiome (fungus).

The microbial organisms found in the gastrointestinal tract of animals is recognized as a critical component of host health. Weaning is a period of stress, dietary changes, and a predisposition to infections, making it a time point of interest to industry. ARS scientists in Beltsville, Maryland, performed the first in-depth analysis of the fungal microorganisms present in the gastrointestinal tract of

piglets between birth and transition to postweaning life, and demonstrated that a dynamic shift occurs in fungal populations at the time of weaning, particularly a dominance of the fungus *Kazachstania slooffiae* in weaned piglets. This dramatic shift in the fungal microorganisms in piglets has not been previously reported and suggests that milk may suppress fungi in the gut. Furthermore, the consequences of the dramatic onset of fungal microorganisms in the gut after weaning is not known, but the trajectory of fungal development could influence future immune competence. Further research could support the development of interventions and dietary modifications to enhance piglet performance and increase swine herd productivity. (NP 101, Project No. 8042-31440-001-00D)

Systems biology tool for the analysis of agriculturally important bacteria.

Systems biology is the computational modeling of genes, their interactions, and the influence of the environment on the system. Until now, microbiologists and other researchers working on bacteria-related problems in animal disease, food safety, bioengineering, and other agricultural domains were not able to efficiently create realistic systems biology models. Through an ARS Scientific/High Performance Computing collaborative research initiative (SCINet) including ARS researchers in Clay Center, Nebraska, and collaborators with industry and at Iowa State University, the Pathway Tools systems biology analytical platform was customized to run on Amazon Web Services to host systems biology models of bacterial field isolates sequenced and assembled by USDA. The primary beneficiaries of this resource are researchers and others wishing to use, create, and publish systems biology models that relate bacterial genes to key bacterial functions or physical traits. These models will assist in generating evidence-based strategies to combat the effects of bacterial infection, improve food safety protocols, and promote solutions to bacteria-related problems in agriculture. (NP 103, Project No. 3040-32000-034-00D)

Understanding and detecting *Brucella abortus* vaccine RB51 shed in milk.

Brucella abortus is a highly contagious bacterial pathogen for livestock and humans and is classified as a select agent because of its potential use as a bioweapon. In the United States, a vaccine strain called RB51 is routinely used to vaccinate female calves to prevent infection and limit human exposures. Over the past 2 years, people in at least three States have been infected with the B. abortus RB51 vaccine strain after drinking unpasteurized milk. ARS scientists in Ames, Iowa, collaborated with colleagues at the Centers for Disease Control and Prevention and the Animal and Plant Health Inspection Service to better understand why some cattle vaccinated as calves shed RB51 in their milk as adults. Their results showed cattle that shed RB51 in milk have a different type of immune response than animals that do not shed RB51 in their milk. ARS further developed an assay that can detect cattle-shed RB51 in milk. Due to the widespread use of RB51 vaccination in cattle, this research is critical to the work of protecting public health and understanding why some cattle become persistently infected with the vaccine strain. (NP 103, Project No. 5030-32000-224-00D)

Study reveals pigs can transmit foot-and-mouth disease (FMD) before showing signs of sickness.

The FMD virus spreads much more aggressively in pigs than previous research suggested, according to ARS scientists at the Plum Island Animal Disease Center. A new study shows that pigs infected with FMD can infect other pigs just 24 hours after becoming infected, long before showing any clinical signs of FMD. Before this research occurred, experts believed FMD transmission in pigs did not occur before visible signs of illness developed, so previous disease-dynamics models to predict disease impacts and estimate outbreak resource requirements did not account for the impact of preclinical transmission. When ARS scientists and Animal and Plant Health Inspection Service collaborators used this new information in models that project disease transmission rates, estimates for the number of U.S. farms that would be affected by FMD outbreaks increased 40 percent. This increase translates into 166

additional farms and more than 664,000 additional pigs requiring euthanasia. Failure to account for new information such as this could make the difference between preparing for a limited, well-controlled FMD outbreak in the United States costing $3 million over 2 months and a catastrophic nationwide epidemic costing $20 billion over 1 year. Infectious disease modeling is a critical part of preparedness and protection of U.S. livestock. Research such as this provides critical information to help build better models to protect livestock industries from FMD. (NP 103, Project No. 8064-32000-061-00D)

A new United States swine pathogen database (https://swinepathogendb.org).

In recent years, several deadly viral diseases of pigs have emerged in the United States causing hundreds of millions of dollars in economic damage. To effectively respond to these diseases or detect new disease incursions or viral variants, it is critical to have a database of currently circulating viral genetic sequences and associated tools to analyze the sequences. ARS scientists in Ames, Iowa, created such a database for porcine reproductive and respiratory syndrome virus, *Senecavirus* A, and porcine epidemic diarrhea virus using nucleotide sequences and related metadata found in GenBank, part of the National Center for Biotechnology Information, and from clinical cases detected by key veterinary laboratories. Presently, the South Dakota Animal Disease Research and Diagnostic Laboratory, Iowa State Veterinary Diagnostic Laboratory, and Kansas State University Veterinary Diagnostic Laboratory have submitted more than 2,000 sequences. A suite of web-based tools allows stakeholders, researchers, and veterinarians to quickly search for genetic sequence information, identify similar viruses, and browse virus genomes to inform their research and control efforts. Databases such as these will greatly increase researchers' understanding of endemic circulating viruses and speed response efforts by helping them to quickly identify new viral variants. (NP 103, Project No. 5030-32000-118-00D)

Easily deployed spatial repellent provides protection from disease vectors.

Standard pesticide sprays can reduce mosquito and biting fly attacks. However, they also contribute to insecticide resistance, which undermines their long-term utility. ARS scientists in Gainesville, Florida, and collaborators determined that the spatial repellent transfluthrin applied to strips of camouflage netting and geotextiles used ubiquitously by the U.S. military can be easily transported and attached to perimeters and structures to create a rapid shelter from biting and disease-vectoring insects. Significant reductions of incursions by mosquitoes, sand flies, and other biting flies were documented in protected perimeters across four ecologically distinct and militarily relevant environments. Thus, deployment of vector protection occurred without having to wait for intervention by mosquito and vector control units. In addition, the spatial repellent protected the perimeters without causing death of the targeted pests. By not killing the insects, the development of insect resistance is impeded by allowing insecticide-susceptible insects to dilute populations of insecticide-resistant pests. (NP 104, Project No. 6036-32000-050-00D)

Reduction of an invasive weed in the cattle fever tick quarantine zone.

The giant reed is an invasive weed in the cattle fever tick Permanent Quarantine Zone, where it clogs portions of the Rio Grande River and reduces border visibility. Two biological control agents of the giant reed, the arundo wasp and the arundo scale, were released in 2009 and 2010, respectively. Nine years after the release of the scale, ARS scientists in Kerrville, Texas, documented a 55 percent reduction of above-ground giant reed stands in areas where both the arundo wasp and scale were used as a biocontrol agent compared with areas where the wasp alone was used. Despite its low dispersal rate, the impact of the arundo scale as a biological control agent was augmented when used together with the wasp. Reducing stands of giant reed reduces the ideal habitat for southern cattle fever ticks, which helps maintain the cattle fever tick quarantine. (NP 104, Project No. 3094-32000-039-00D)

Salivary proteins of biting midges associated with virus transmission in livestock.

Until this research occurred, the extreme efficiency with which biting flies (midges) can transmit some viruses was not clearly understood. ARS scientists in Manhattan, Kansas, discovered that when virus-infected midges bite seeking blood, they transmit the virus as well as 45 proteins in their saliva that are critical for successful acquisition of a bloodmeal. A mouse model showed these salivary proteins promoted rapid infection and systemic dissemination of midge-transmitted viruses via the lymph system. Additionally, saliva-induced blood vessel dilation encourages virus replication and dissemination via the circulatory system. This research advances our understanding of the complex myriad of proteins in midge saliva and provides insights into their functional role in blood feeding, virus transmission, and viral disease pathogenesis. This fundamental research guides the development of methods to impede virus transmission in livestock. (NP 104, Project No. 3020-32000-007-00D)

Improved diagnostic kit in commercial development for all quarantined fire ant species.

The red imported fire ant and the black imported fire ant are invasive species that cost the United States more than $6 billion annually in damage and control measures. The Federal imported fire ant quarantine program requires commodities to be free of both species before leaving quarantine. ARS scientists in Gainesville, Florida, with Animal and Plant Health Inspection Service scientists in Biloxi, Mississippi, developed a simple-to-use and portable identification kit (analogous to a home pregnancy test) that can distinguish both fire ant species from all other ants in a single, 10-minute test. The speed of the test curtails extended delays at inspection stations by eliminating the need to send off samples for identification. Being able to distinguish the black imported fire ant is an important improvement over the previous kit (InvictDetect) the scientists developed, which detected only the red species. The improved kit provides a new tool for regulatory agencies in the United States and other countries to enforce

quarantine protocols that limit the spread of one or both invasive ant species. The license for this new technology has been acquired by Agdia Inc. and is currently being developed for commercial distribution. (NP 104, Project No. 6036-32000-048-00D)

ARS trout germplasm selected by a U.S. producer for use in commercial egg sales and production. Most rainbow trout farmers do not manage their own broodstock, but instead purchase eggs for production from outside sources. The second largest commercial egg retailer in the United States obtained trout germplasm noted for growth and utilization of plant protein feed from ARS researchers in Aberdeen, Idaho, and is now selling eggs from these lines. The company is expressly marketing eggs from the ARS line as being hardier and has demonstrated their improved growth rate under different environmental conditions compared with eggs supplied by other vendors in the United States and abroad. In addition, the company is the second-largest commercial producer of rainbow trout and uses ARS germplasm almost exclusively in its production farms. (N P106, Project No. 2050-21310-005-00D)

Comparison of growth and carcass yield of Delta Select and Delta Control strains of channel catfish.

Improved catfish germplasm will allow U.S. catfish farmers to reduce their production costs and remain competitive in the global seafood market. ARS scientists in Stoneville, Mississippi, initiated a selective breeding program to develop the Delta Select strain of channel catfish, which demonstrates a superior growth rate and meat yield, traits that are important to catfish producers and processors. A series of performance trials were conducted to compare the growth and meat yield of the Delta Select strain with those of the Delta Control strain, an unselected strain representative of channel catfish currently being grown by U.S. farmers. The Delta Select strain grew 30 percent faster and had 0.25 to 0.80 percent higher meat yield than the Delta Control strain, demonstrating that selection has improved both traits in

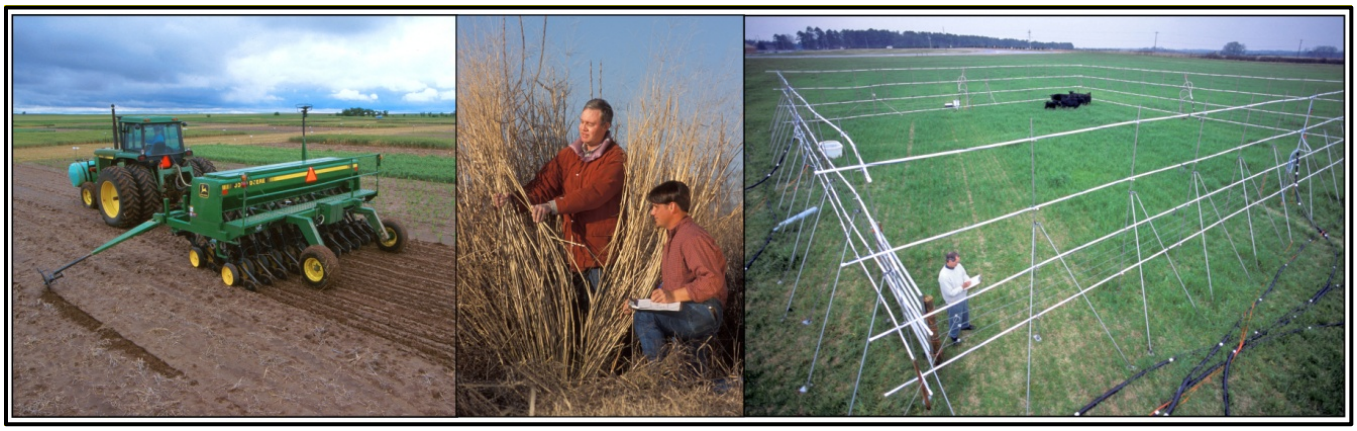
the Delta Select strain. Approximately 150,000 2-year-old Delta Select strain channel catfish will be available for release to farmers during fiscal 2020 to allow U.S. catfish farmers to be more efficient and profitable. (NP 106, Project No. 6066-31000-012-00D)

Selective breeding improves resistance to bacterial coldwater disease and columnaris disease. Antibiotics are used to control these diseases of rainbow trout and few alternative control strategies currently exist. ARS researchers in Leetown, West Virginia, evaluated the genetics of resistance to both diseases in two rainbow trout populations. Resistance was found to be heritable and favorably linked, suggesting that a rainbow trout's resistance to both diseases is at least partially due to the same genes. Based on these studies, molecular genetic techniques are now being used to identify the actual genes that affect disease resistance. Commercial breeders who select rainbow trout strains for their improved resistance to only one of the diseases can expect to reduce the impacts of both diseases in their fish populations. (NP 106, Project No. 8082-32000-006-00D)

Waterborne exposure to select clay minerals protects catfish against virulent *Aeromonas hydrophila* infections.

Aeromonas hydrophila is one of the most widespread bacterial pathogens affecting freshwater fish, and a new strain has severely impacted the catfish industry over the last decade. ARS scientists in Auburn, Alabama, evaluated the effect of treatment with kaolin, an inert clay, for controlling *A. hydrophila* outbreaks. Tests revealed that kaolin clay significantly blocked the movement and binding ability of *A. hydrophila* to catfish mucus. Kaolin treatment at a level of 0.1 percent led to a significant improvement in survival (66.7 percent) of experimentally infected catfish compared with survival (28.9 percent) among untreated fish. Kaolin treatment did not alter the growth of *A. hydrophila,* but bacterial levels in test suspensions were significantly reduced within 15 minutes after kaolin treatment, indicating the rapid

formation of complexes that settle between kaolin and bacteria. These findings suggest that integrating kaolin into some production settings may be beneficial, particularly in scenarios where the use of antibiotics is not possible, or when it is likely that an *Aeromonas* outbreak could occur following stressors such as grading, stocking, or transport of fish. (NP 106, Project No. 6010-32000-026-00D)



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**

Stepped spillway design criteria adopted by Federal agencies and architectural and engineering consulting firms.

Roller-compacted concrete (RCC) stepped spillways provide embankment overtopping protection and increased capacity for aging embankment dams. An ARS researcher in Stillwater, Oklahoma, developed a systematic, step-by-step RCC spillway design guideline to rehabilitate aging embankment dams. The Natural Resources Conservation Service (NRCS) is incorporating the criteria into its National Engineering Handbook and expects it to be implemented on approximately 1,200 aging USDA dams. NRCS experts say the criteria will provide construction cost savings ranging from $600 million to $1.2 billion compared with other embankment overtopping protection systems. The U.S. Army Corps of Engineers is also integrating the criteria into its revised spillway design technical manual (EM 1110-2-1603). In addition, this research has become an industry standard among architectural and engineering

consulting firms across the United States for upgrading aging dams. This technology is assisting dam safety engineers in preserving the $2.3 billion in annual benefits (i.e., flood control, rural and municipal water supplies, irrigation for agricultural production, recreation, and wildlife habitat among others) provided by USDA dams. (NP 211, Project No. 3072-13000-010-00D)

Improving water quality with field-edge nitrate removal.

Saturated riparian buffers are a promising new development in efforts to remove nitrate from farm field drainage; however, only limited data are available on the effectiveness of the practice. By monitoring 6 sites for 2 to 9 years, ARS researchers in Ames, Iowa, and Iowa State University researchers have shown that saturated riparian buffers can remove 40 to 90 percent of nitrate leaving a farmer's field before it enters a stream or river. The scientists also demonstrated that nitrate removal occurs primarily from denitrification (the conversion of nitrate to nitrogen gas) and that this conversion does not increase the generation of nitrous oxide, a powerful greenhouse gas. This research has led the NRCS to develop a new conservation practice standard for implementation on Midwest U.S. farms. (NP 211, Project No. 5030-13000-011-00D)

Alternate cropping systems can conserve groundwater.

Reduced irrigation well capacities due to declining groundwater levels in the Ogallala Aquifer will eventually limit the production of corn in the northern High Plains of Texas, which currently is one of the region's most profitable crops. Alternatively, less water-intensive crops may conserve groundwater while allowing producers to remain profitable. To solve this challenge, scientists from ARS in Bushland Texas, and the Texas A&M AgriLife Research and Extension Service used the Soil and Water Assessment Tool, a hydrologic model, and equipped it with a newly developed irrigation program to simulate water use associated with soybean, sunflower, and grain sorghum. Results indicated that

irrigation amounts were reduced by 19, 21, and 32 percent, respectively, compared with amounts of water used to grow corn. Substituting grain sorghum for corn at 70 percent of its optimum irrigation amount resulted in greater income per acre, whereas substituting sunflowers for corn at 80 percent of the optimum irrigation amount for corn had little effect on income per acre. These results are of interest to farmers, crop consultants, and regional water policymakers who need to identify crops other than corn that can be grown where groundwater availability is limited. (NP 211, Project No. 3090-13000-015-00D)

New bank stability assessment technology helps protect rivers and streams.

The erosion resistance of streambank soils can vary significantly in space and time. Current bank erosion prediction technology does not account for this variability, which makes it difficult to select appropriate soil erosion-resistance values when assessing bank erosion. ARS researchers in Oxford, Mississippi, used stochastic analysis to develop a new way of estimating expected bank erosion by incorporating parameters such as soil erodibility and shear strength into ARS's widely used Bank Stability and Toe Erosion Model (BSTEM). The new BSTEM version is able to determine the probability that bank retreat magnitudes may be exceeded. This is crucial information when critical infrastructure is located near rivers and streams. As part of the $1.6 billion American River Common Features project, the new technology is currently being used by the Sacramento District of the U.S. Army Corps of Engineers to prioritize bank protection measures to prevent levee failure around the City of Sacramento, California. (NP 211, Project No. 6060-13000-026-00D)

Decision support tool promotes adoption of precision agricultural practices on small and medium sized farms.

Auto-guided tractors can reduce on-farm inputs by as much as 20 percent and save producers $10.8 to $13.5 million annually through gains in equipment efficiency and enhanced yields. Moreover, auto-guided tractors also help producers reduce the possible overapplication of fertilizers and herbicides, which in turn reduces the negative environmental footprint of crop production and avoids unintentional input costs. ARS scientists in Fayetteville and Booneville, Arkansas, and University of Arkansas research partners developed a decision support tool that promotes the adoption of precision agriculture technologies such as auto-guided tractors and other self-propelled machinery that reduce overapplication of on-farm nutrients and inputs by 10 to 20 percent. Their Tractor Guidance Analysis software incorporates parameters tailored for the size of different farming operations and generates estimates for 1) reductions in seed, organic and inorganic fertilizer, and chemical inputs given differing terrain attributes; 2) efficiency gains and feasibility of technology adoption by determining break-even prices based on farming operation type, farm size, and capital investment requirements; and 3) subsequent soil health and water quality effects from reduced agricultural inputs based on in-field data. This tool was released in 2018, and scientists have provided hands-on training to farmers and agricultural workers via field days and stakeholder meetings. The Tractor Guidance Analysis software has been especially effective in advancing the use of auto-guided tractors and self-propelled machinery on small farms that have not traditionally adopted precision agriculture technologies. (NP 212, Project No. 6022-63000-005-00D)

Innovative manure treatment addresses nutrient pollution problems and creates commercial products.

Manure is often used as a farmland amendment to provide nitrogen, phosphorus, and organic matter for crops. Excess phosphorous found in some manures, however, can contaminate rivers, lakes, and bays through runoff. The recovery of phosphorus and proteins from manure prior to application to fields could be advantageous to offset treatment and storage costs, and to lessen the environmental impacts to land. ARS researchers in Florence, South Carolina, developed a new biorefinery process that recovers value-added phosphorus, proteins, and amino acids, and leftover solids from manures. An additional breakthrough came when sugars from sucrose, sugarbeet molasses, and peach waste were used as natural acid precursors to further lower treatment costs. These precursors allowed rapid fermentation, which produced abundant acids. These acids extracted nearly all the phosphorus and the acids also caused nearly all of the proteins to be concentrated in an easy-to-collect precipitate. The process is also effective at extracting phosphorus and proteins from other biological materials such as algae and soybean meal. The recovered proteins can be used to produce amino acids, and the recovered phosphorus can be used as a recycled material to replace commercial phosphate fertilizers. This innovation provides a means to create new revenue stream from farm wastes. (NP 212, Project No. 6082-12630-001-00D)

Inexpensive vegetative buffers around poultry facilities reduce air pollution.

Vegetative environmental buffers (VEBs) are composed of selected trees, shrubs, and/or tall grasses that are frequently installed near the exhaust fans of poultry houses to control and reduce the off-site transport of potential pollutants such as particulates and ammonia. NRCS has historically developed guidelines and tools for the design and selection plants for VEBs, but the effectiveness of VEBs in controlling emissions has not been adequately quantified. ARS researchers in several locations

(Florence, South Carolina; Beltsville, Maryland; Lubbock, Texas; and Ames, Iowa) in collaboration with colleagues at universities in Delaware, Iowa, Maryland, Oklahoma, and Alberta (Canada), used state-of-art laser systems and micrometeorological techniques to quantify dispersion and removal of particulates and ammonia from a poultry house surrounded by a VEB. Particulate capture efficiency ranged from 20 percent to 70 percent depending on meteorological conditions; ammonia removal was 22 percent, and net downwind ammonia dispersion was reduced 51 percent. NRCS is using these results to refine and bolster the standards that define the mitigation potential and limitations of the vegetative buffers. (NP 212, Project No. 6082-12630-001-00D)

Perennial living mulch systems increase sustainability of corn and soybean production.

Perennial living mulches are a farming management option that provide the environmental benefits of cover crops, such as reductions in both erosion and chemical runoff, but without the need to replant each year. One plant that is commonly used as a perennial living mulch is kura clover, a long-lived legume that spreads by rhizomes, but the factors affecting its agronomic performance and nutrient management are not well defined. ARS scientists in St. Paul, Minnesota, have been developing the management systems needed to successfully integrate kura clover-based living mulch systems into corn and soy production. They have also developed a novel rotary zone tillage (RZT) system that, in contrast to conventional strip tillage, create 30-cm rows, which more effectively eliminates early season kura clover and reduces corn competition for light, water, and nutrients. The scientists have also shown that due to kura's nitrogen fixation ability, first-year corn following 2 to 3 years of kura management for forage does not require nitrogen fertilizer to maximize yield and profitability, and second-year corn requires only a reduced application of nitrogen fertilizer. The net economic return from corn grain and stover in the kura-corn system averaged over two seasons was $138 per hectare more than conventional corn production. The combination of the RZT management of the kura living mulch cropping system

provides a promising system for corn growers that can return significantly greater economic and ecological outcomes. (NP 212, Project No. 5062-12000-010-00D)

Low-cost precision technology helps with peak rangeland production.

Rangeland producers need timely, reliable, and easy-to-understand information about the condition of their land to make management decisions. Critical information needed for managing grazing cattle productivity include timing of establishment, growth, peak production, and reproduction of various pasture plants. Producers traditionally collect this information during field visits, which are expensive and time intensive. Through extensive field work in dominant ecosystems of the Great Basin and Chihuahuan Desert, ARS scientists in Reno, Nevada, and Las Cruces, New Mexico, determined that inexpensive, land-based, plant phenology cameras can be used to quantify changes in mixed shrub-grasslands and meadow ecosystems. These plant "phenocams" offer producers a powerful way to improve their ability to decide when grazing time is at its peak, the best time to apply herbicides, and when to reduce vegetative fuel loads that increase the risk of wildfires. (NP 215, Project No. 2060-13610-003-00D)

Active stakeholder participation in research leads to community-focused, adaptive rangeland management.

Agricultural producers and industry personnel have diverse perspectives on production systems and environmental issues. Fully engaging them as co-developers and co-participants in agricultural research, from discovery to application to outreach, holds great promise for advancing sustainable agricultural intensification. ARS scientists in Fort Collins, Colorado, and Cheyenne, Wyoming, and partners initiated a research project in 2011 that generated practical suggestions for improving the management of complex agroecosystems and provided a model for transdisciplinary research to address

contemporary societal issues. Collaborators included scientists from the University of Wyoming, Colorado State University, and Texas A&M University, and a diverse group of ranchers, State and Federal land managers, and nongovernmental conservation organizations. Lessons learned have been implemental locally by ranchers and the U.S. Forest Service, and extended regionally by outreach engagement through the USDA Northern Plains Climate Hub, the USDA Long-Term Agroecosystem Research network, the University of Nebraska, and even internationally. With its emphasis on human dimensions and social-ecological systems, this project has been showcased by the Group of Twenty (G-20) Agroecosystem Living Laboratories effort as the primary U.S. example of stakeholder engagement in participatory research. (NP 215, Project No. 3012-21610-002-00D)

Adjusting fall grazing schedules for finishing cattle increases profits and range sustainability. To maximize economic returns, ranchers in semiarid environments must decide each year when to move cattle from rangeland to feedlots for finishing. They traditionally do this in October. The decision is based on expected cattle weight gain given rangeland conditions and market prices, but this forecasting is increasingly challenged by changing climate and highly variable precipitation within and across years. ARS scientists in Cheyenne, Wyoming, and Fort Collins, Colorado, in collaboration with scientists from Argentina and the University of Wyoming, used livestock gain and economic market data from 2003 to 2017, which represented a range of weather conditions, to quantify differences in net revenue based on the date cattle were delivered for finishing. There was wide revenue variability, which highlights the economic challenges for individual operations and rural economies in the region. However, because livestock gains were negligible from early September to the end of the grazing season, removing cattle from pastures in early September can increase net revenue compared with typical October removal. Early removal also provides ecological advantages of more plant residue for soil cover and a longer rest

period for healthier vegetation. This information will help regional cattle producers improve their economic and ecological sustainability. (NP 215, Project No. 3012-21610-002-00D)

Mineral supplementation increases productivity and profitability of cattle grazing wheat.

Giving supplemental feed to grazing cattle is a good way for producers to increase net returns to the livestock enterprise. Wheat pasture is a unique resource in the southern Great Plains because it provides income from both the grain crop and body weight gain by grazing cattle. Given this dual income source, many producers do not supplement the cattle diet with mineral mixtures to increase cattle performance even though mineral analysis has shown that wheat herbage is deficient in calcium. ARS scientists in Woodward, Oklahoma, examined the practice of providing high-calcium and trace mineral mixtures to cattle grazing in a winter-wheat pasture to compensate for the high potassium in wheat herbage. The cattle given supplemental minerals had a 43 percent faster average daily body weight gain than cattle whose diets did not include supplemental minerals, and at the end of the grazing period supplemented cattle weighed as much as 6 percent more than cattle that did not receive supplements. Mineral intakes averaged 4.4 ounces per day, resulting in a cost of supplement per pound of weight gain of $0.09 (assuming a mineral cost of $0.025/ounce). Producers can use this information to improve cattle weight gain and increases the net return to their stocker cattle enterprises. (NP 215, Project No. 3074-21630-011-00D)

Corn and cattle profitability improved by grazing corn crop residue.

Having beef cattle graze on corn residue is a simple and economical practice for integrating crop and livestock production in the central United States. However, the overall economic value of this practice was unknown. ARS scientists in Lincoln, Nebraska, and university colleagues determined that this type of grazing annually returned $95 million to crop producers in Kansas, Nebraska, North Dakota, and

South Dakota. The annual gross value for grazing corn residue for cattle producers was $191 million in those States. Although challenges exist to expand corn residue grazing, opportunities also exist to increase the practice of this cost-efficient winter forage alternative. (NP 216, Project No. 3042-11210-003-00D)

Carbon can be removed from the atmosphere and stored in soil by intercropping bioenergy crops with trees.

Perennial herbaceous crops such as switchgrass are important sources of cellulosic biomass for the developing bioenergy industry. Assessments of how much carbon will be lost or sequestered into soil and the turnover rates of that carbon are needed to assist producers and policymakers who need to determine the long-term sustainability of biomass production. The natural abundance of soil carbon was used to calculate the quantity and turnover of soil carbon in a switchgrass/poplar intercropping system. After 4 years of cropping, soil organic carbon increased 16 percent in the 0- to 15-cm depth, and on average, 10 percent of this soil organic carbon was derived from switchgrass. The results show that intercropping switchgrass with hybrid poplar gives forest plantation landowners greater economic returns from biofuel production by improving water use and nutrient cycling. Intercropping also promotes additional ecosystem services including carbon sequestration. These benefits directly affect air, water, and soil quality, which are increasingly challenged by climate change. (NP 216, Project No. 3098-11000-001-00D)

Organic agriculture's risk of phosphorus pollution is mitigated with legume cover crops.

Manure is a potent source of both nitrogen and phosphorus. Organic systems often use manure as a nitrogen source, but this can lead to excessive phosphorus application and runoff into waterways. Legume cover crops supply enough nitrogen to reduce poultry litter application requirements in organic

corn production systems, enabling farmers to mitigate phosphorus pollution. In a 2-year study at three organic sites in Maryland, ARS scientists in Beltsville, Maryland, found that poultry litter application can be reduced by half and still achieve the same corn grain yield when used in conjunction with a legume cover crop. These results will be of interest to farmers, environmentalists, policy experts, and others concerned with the health of the Chesapeake Bay and other estuaries impacted by agricultural losses of nitrogen and phosphorus. (NP 216, Project No. 8042-21660-005-00D)

U.S. beef cattle production has a relatively low environmental footprint.

The U.S. beef industry is a major contributor to the national and global food system and economy. Increasing productivity in an environmentally, economically, and socially sustainable manner is of concern to both producers and consumers. Cattle production systems are very complex, with many components and interactions, so quantifying and measuring sustainability is challenging. Through a comprehensive national assessment, ARS scientists in University Park, Pennsylvania, in collaboration with the National Cattlemen's Beef Association, found beef cattle production emitted 3.3 percent of U.S. greenhouse gas emissions, produced 15 percent of reactive nitrogen losses, used 0.7 percent of fossil energy, and consumed 5.8 percent of its fresh water. When these figures are expressed per unit of meat produced, they compare very favorably with global averages. These data provide a baseline for comparison with future assessments and the evaluation of potential benefits of mitigation strategies. (NP 216, Project No. 8070-66000-001-00D)

Climate Hub information dissemination.

In response to extreme weather (e.g., late spring freeze, extreme cold, and flooding/wetness) in the Midwest and Northern Plains, the Midwest Climate Hub translated and packaged relevant USDA science/regional crop production information, regional partner products, and real-time National Weather

Service outlooks to provide timely decision support to crop and livestock producers. This information directly supported programming by USDA personnel, extension specialists, and producers via webinars, written outlooks, workshops, websites, meetings, talks, and various other media. A special June webinar drew about 65 attendees. Regular monthly partner webinars had 110 to 130 producers, decision-makers, and Tribe and media representatives. Eighteen biweekly agricultural outlook newsletters reached more than 1,000 people via mailing lists and thousands more via social media. Extension received weekly/monthly updates. (NP 216, Project No. 5030-11610-005-00D)

Southwest Drought Learning Network improves regional drought research and land management. The Southwest Climate Hub (SWCH), through a regionally coordinated approach to drought, communicates stakeholder concerns to researchers and translates science into actionable information and tools. In 2019, three drought workshops attracted more than 130 participants from USDA agencies, Tribes, and other sectors. SWCH provided drought and precipitation information at six additional Tribal meetings attended by more than 370 Tribal professionals in Arizona and New Mexico. The SWCH also increased precipitation monitoring across the region. Drought related tools and resources were presented at the Universities Council on Water Resources and International Fire Behavior and Fuels annual conferences, leading to actionable science. One of the most important outcomes from these activities is expanding our knowledge of partner and stakeholder needs. These interactions inspired the new Southwest Drought Learning Network that will continue to be developed in 2020. (NP 216, Project No. 3050-11210-009-00D; C/PS)

CROP PRODUCTION AND PROTECTION

National Programs:

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

New citrus trees for U.S. growers.

Huanglongbing (HLB) disease has been devastating to the Florida citrus industry and severely threatens citrus production in other parts of the United States. The use of tolerant rootstocks and scions can be effective in ameliorating disease effects. ARS researchers in Ft. Pierce, Florida, released three HLB-tolerant citrus rootstocks that produced sweet orange trees with improved health, fruit yield, and fruit quality over multiple years in an HLB-endemic environment. ARS researchers also released the first citrus scion cultivar, called 'US SunDragon', that has good fruit quality and tolerance to HLB disease. 'US SunDragon' is being widely tested in Florida as a breeding parent, for niche fruit, and for home-owner plantings. Initial tests of juice quality show promise for inclusion of 'US SunDragon' in orange juice blends. The new tolerant rootstocks and scions will allow continued profitable production of citrus in the presence of HLB. (NP 301, Project No. 6034-21000-018-00D)

New tomato flavor gene discovered.

Tomatoes are the most valuable fruit crop globally and are among the most widely consumed fruit or vegetable in the United States at 70 pounds per capita annually. Tomatoes are also an important source of the antioxidant lycopene, which gives tomatoes their red color, and beta-carotene, which our bodies convert to vitamin A. However, many consumers complain that store-bought tomatoes lack flavor. ARS researchers in Ithaca, New York, identified a rare version of the TomLoxC gene that is prevalent in the wild ancestors of tomato but is absent from most cultivated lines, including the genome of Heinz 1706, the reference tomato genome sequence. TomLoxC contributes to tomato flavor by catalyzing the synthesis of aromatic compounds that taste panels show consumers strongly prefer. TomLoxC, while still rare, is seeing a resurgence in modern tomato varieties in parallel with a renewed interest in flavor by breeders attempting to address consumer demands. (NP 301, Project No. 8062-21000-047-00D)

New releases solve soybean yield and protein bottleneck while enhancing diversity.

The narrow genetic base of soybeans grown in the United States has been a known bottleneck to soybean yield enhancement, and it has increased crop vulnerability to new threats. In addition, the meal protein content of current U.S. soybean cultivars has dropped below the market standard of at least 48 percent due to the negative correlations between seed protein and yield. To stay competitive in the international market, U.S. soybean growers and processors require high-yielding soybean with at least 48 percent protein in the meal. In response, ARS scientists in Raleigh, North Carolina, released two germplasm lines that will be very useful for developing high-yielding soybean cultivars with high meal protein. One line, USDA-N7004, exhibits high yield potential and greater protein meal content. The line traces 25 percent of its exotic pedigree from a Japanese cultivar maintained in the USDA soybean germplasm collection. USDA-N6004 is a high-yielding germplasm that traces 50 percent of its pedigree to a different Japanese cultivar. These public releases are being used by commercial soybean breeders to

boost competitiveness and profitability of U.S. soybean in the world markets and to expand the diversity of soybeans in the United States. (NP 301, Project No. 6070-21220-069-00D)

Cloning wheat gene for resistance to *Fusarium* head blight (FHB).

FHB is a destructive wheat disease throughout the world, but a major gene for FHB resistance that was originally identified in Chinese germplasm, Fhb1, has since been introduced into wheat germplasm around the world. ARS scientists in Manhattan, Kansas, cloned Fhb1 and showed that the gene encodes a defective form of a putative histidine-rich calcium binding protein. The functional form of the gene, present in susceptible cultivars, appears to be a susceptibility gene that allows the fungus to spread in the spike. Cloning of Fhb1, reports of which were published in Nature Genetics, provides ideal diagnostic markers for selective breeding and opens the possibility of using bioengineering approaches to further enhance FHB resistance. (NP 301, Project No. 3020-21000-011-00D)

A new table grape.

ARS researchers in Parlier, California, have released a new early season table grape named 'Solbrio' that has both exceptional eating quality and reduced needs for cultural input from growers. Consumers have shown a strong interest in the new variety because of its large berry size, crisp and crunchy flesh, and fully colored berries. Many of the standard—and expensive—cultural practices used to enhance characteristics of current table grape varieties were evaluated on the new variety, but none of the treatments produced a significant change on berry quality or yield. Hence, growers are very pleased with the new variety that is both easy and inexpensive to grow. (NP 301, Project No. 2034-21220-007-00D)

Improving resistance to iron deficiency chlorosis (IDC) without lowering soybean yields.

Soybean yield loss due to IDC is estimated to exceed $150 million annually in the North Central United States. Because IDC-tolerant lines produce low yields, farmers prefer to use higher yielding, albeit IDC-susceptible lines and to apply expensive foliar sprays. ARS researchers in Ames, Iowa, and colleagues at Iowa State University aimed to develop high-yielding IDC-tolerant lines, but it first required an understanding of soybean responses to IDC. Research in model species identified IDC tolerance genes but failed to translate them into improved iron efficient agricultural crops. The scientists used novel genomic technologies to identify and characterize genes and pathways in soybean that are important in IDC tolerance. They discovered 10,000 genes that were involved in iron uptake, but that also regulated a trade-off between plant growth and stress responses, a function that is unique to soybean. Gene expression studies were coupled with observations of genetic marker differences across the genomes of 450+ diverse soybean lines to determine IDC tolerance, thus allowing mapping of the precise genome location contributing to IDC tolerance in soybean. Remarkably, this discovery further separated an unexplored IDC tolerance gene location identified more than 35 years ago into four discrete genomic locations, each containing genes regulating iron uptake, defense, or growth pathways. The markers, genes, and pathways were publicly released and provide a valuable resource for improving soybean responses to iron stress. (NP 301, Project No. 5030-21220-006-00D)

Early detection through reduced RNA integrity of seed aging in plant germplasm samples.

Plant germplasm stored in genebanks must be monitored for viability to ensure that samples are regenerated before they die. The current gold-standard test is a germination assay, which is labor-intensive, consumes much of the supply of valuable seeds, and is insensitive during the early, asymptomatic stage of seed aging. ARS scientists in Fort Collins, Colorado, developed a simple assay, based on degradation of the nucleic acid RNA, that detects the rate of aging in seeds during the

asymptomatic period. The assay consumes few seeds per sample and can be developed into a kit to facilitate automated monitoring. This new monitoring tool can accurately predict when seeds should be regenerated while preventing unnecessary consumption of seeds for testing. Knowledge of the fate of RNA in aging dry cells of seeds could enable automation of seed testing to increase plant genebank operational efficiency and reveal key information about the biological nature of seed aging. (NP 301, Project No. 3012-21000-016-00D)

World's first spinach cultivar with red leaves.

Spinach has always been known as a green leafy vegetable. Although there are currently some red spinach cultivars on the market, the red color is limited to the veins of the leaves. ARS researchers in Salinas, California, developed 'USDA Red', the world's first spinach variety with red color on the surface of the leaves. 'USDA Red' had 65 percent higher betacyanin content and 53 percent higher antioxidant capacity than red-veined spinach cultivars on average in field trials conducted between 2015 and 2018. The betacyanin adds another punch to a plant already loaded with phytonutrients, making spinach a true "super food." The red spinach may bring some excitement to the spinach market and attract consumers to the colorful new product, helping increase the consumption of spinach and aid in the fight against obesity. (NP 301, Project No. 2038-21530-002-00D)

'Castella', a new club wheat, released for the intermediate rainfall region of Washington State.

Club wheat constitutes a significant portion of the wheat export market in the Pacific Northwest, but current club wheat cultivars are either susceptible to low falling numbers or to stripe rust. ARS scientists in Pullman, Washington, developed and released 'Castella' club wheat, which is resistant to stripe rust, aluminum, and Hessian fly, and possesses excellent club wheat end-use quality. A combination of single seed descent, marker-assisted selection, and multilocation field trials was used to develop 'Castella' club

wheat from a cross with a diverse pedigree that included breeding lines from Arkansas, New York, and Washington. This diverse pedigree has resulted in an unusual combination of traits in 'Castella' that will increase marketing opportunities for growers. (NP 301, Project No. 2090-21000-033-00D)

New tools for breeding cold tolerance in chickpea.

Chickpea production has expanded dramatically in the United States, with a greater than 50 percent increase in the number of acres planted with the crop in 2017 compared with 2016. Export demand has been high, and domestic consumption has grown substantially, so additional production is needed. In the United States, chickpeas sown in the autumn can yield substantially more than spring-sown chickpea in regions with mild winters. To accelerate breeding cold-tolerant chickpea to expand the current geographic range of production and improve overall productivity, ARS researchers in Pullman, Washington, worked with Washington State University and Hebrew University of Jerusalem colleagues and identified the approximate locations on the chickpea genome for genes that control cold tolerance and the DNA genetic markers associated with cold tolerance. Those genetic markers will help accelerate breeding chickpeas with greater cold tolerance and thus expand the geographical range of U.S. production. (NP 301, Project No. 2090-21000-032-00D)

Canine detection of Huanglongbing (HLB) in California to mitigate an impending State-wide epidemic.

HLB epidemics continue to spread worldwide and devastate the citrus industry. The key to mitigating HLB is early detection and rapid response. ARS researchers in Fort Pierce, Florida, have trained 20 dogs to detect HLB shortly after a tree has been infected (i.e., within 2 to 4 weeks after infection). The prior gold standard used to detect HLB, polymerase chain reaction (PCR), requires months to perform. The dogs can also detect infection with 99 percent accuracy, whereas the accuracy of PCR detection is

approximately 30 to 35 percent, because even though the assay is good, it is difficult for humans to select infected tissue from a tree with some 200,000 leaves. In 2018–2019, California growers, the California Department Food and Agriculture (CDFA), industry leaders, and regulatory personnel concluded that the canines were more than 92 percent accurate in detecting infection even under highly variable and inhospitable conditions. The canines are being integrated and deployed by CDFA to detect asymptomatic incipient infections of HLB for early response (tree removal). Simulations indicate how the impending epidemic is greatly mitigated by incorporating canine detection teams in early detection practices. (NP 303, Project No. 6034-22000-042-00D)

Proof that Brome mosaic virus (BMV) can cause significant yield loss in U.S. wheat.

BMV is well known to infect many plants, including wheat and other grain crops, but it has long had the reputation of being an unimportant pathogen of crops. Following repeated detection of BMV in Ohio surveys of wheat from 2012 to 2017 at incidences of up to 25 percent, ARS scientists in Wooster, Ohio, and university collaborators showed that all tested Ohio-grown wheat cultivars were susceptible to infection, and that inoculation with BMV at any of four tested growth stages resulted in up to 60 percent yield losses. Some wheat cultivars showed tolerance to the virus; therefore, cultivar selection may minimize grower losses due to this virus infection. Results of this study were published in an April 2019 edition of the journal Phytopathology. (NP 303, Project No. 5082-22000-001-00D)

Release of potato cultivar with broad-spectrum resistance to the golden nematode.

Potato cyst nematodes, including the golden nematode and the pale cyst nematode, are devastating pests of U.S. potato production. Deploying resistant cultivars is the most effective and sustainable means for combating nematode pests. ARS researchers in Ithaca, New York, and Cornell University collaborators developed and released ‘Brodie’, the first potato cultivar that confers resistance to the two pathotypes

(Ro1 and Ro2) of the golden nematode. This new resistant cultivar provides the needed materials for controlling Ro2, a more aggressive population, in the field, thereby helping maintain the success of golden nematode quarantine in the United States. (NP 303, Project No. 8062-22000-022-00D)

Replacing methyl bromide: Adaption of anaerobic soil disinfestation (ASD) for commercial production systems.

The loss of methyl bromide for soilborne pest control left few registered soil fumigants, and these fumigants are not effective for the spectrum of pests that were previously controlled using methyl bromide. This leaves specialty crop growers at risk. ARS researchers in Fort Pierce, Florida, and their cooperators conducted field trials with commercial producers to assess the efficacy of ASD through a combination of composted or pasteurized pelleted poultry manure and feedstock sugarcane molasses applied under totally impermeable film for crop production without chemical soil fumigation. Use of ASD resulted in yields that were equivalent or higher than those attained from chemical fumigation and demonstrated break-even prices, resulting in consistent, positive returns for growers. Demonstration trials on commercial farms, conducted for multiple crops and seasons, resulted in adoption of ASD, particularly in buffer zone areas in which chemical fumigants cannot safely be applied. This approach provides specialty crop producers with an option for pest control for areas in which they currently have none. ASD requires slight modifications to the pre-plant practices currently employed, but provides economic, worker safety, and environmental benefits. (NP 303, Project No. 6034-22000-043-00D)

Mite blood-feeding dogma overturned: Varroa mite feeds instead on bee fat body.

Varroa mite is the greatest factor in honey bee mortality. Reassessing the feeding habits of these parasitic mites in collaboration with University of Maryland cooperators, ARS researchers in Beltsville, Maryland, found that contrary to decades of literature, varroa mites do not feed on honey bee blood

(hemolymph), but instead feed on the insect's fat body. This has important implications for using mite control strategies that involve the bee, since any anti-mite chemical, such as those that silence mite genes, would have to be delivered not to the bee hemocoel (blood system), but rather to the fat body. Since the fat body is also where a bee's hormones are produced, it also helps to explain the mite's devastating effects. (NP 304, Project No. 8042-22000-271-00D)

Morpholinos to the rescue: New chemicals for citrus greening control.

Many bacterial pathogens in plants are difficult to target because they are protected by biofilms. A set of novel morpholino chemicals—small pieces of DNA that are antisense (i.e., oriented in the opposite direction of normal DNA)—were discovered by ARS scientists in Fort Pierce, Florida, to move through the biofilm containing the bacterium that causes citrus greening disease, thus killing the bacteria. Now patented by ARS, this strategy, which also worked in potato against Zebra chip disease, represents a new means to protect fruit, nut trees, and vegetables from numerous important plant diseases. (NP 304, Project No. 6034-22320-004-00D)

New biological control agent for Brazilian pepper tree.

Brazilian pepper tree originated in South America and then became one of the most widespread and destructive invasive species in the Florida Everglades. Efforts to control and eradicate this weed have not been effective and it continues to spread. ARS scientists in Fort Lauderdale, Florida, in collaboration with Argentinian collaborators, recently obtained authorization for field release of a thrips (the insect *Pseudophilothrips ichini*) biocontrol agent. Research has shown thrips that fed under greenhouse conditions reduced Brazilian pepper seedling growth by 80 percent. The new biocontrol agent may provide land managers and farmers with a cost-effective means of controlling Brazilian pepper tree by

reducing the current and expensive reliance on herbicidal control. (NP 304, Project Nos. 6032-22000-012-00D and 0206-22000-008-00D)

One tiny step for a nematode, one big step toward sustainable agriculture in space.

An exciting collaboration between ARS researchers in Byron, Georgia, and industry partners will send beneficial nematodes into space to the International Space Station. Nematodes are small roundworms that typically live in soil and are some of the most abundant animals on earth. The goal is to develop environmentally friendly methods for growing foods in space without using chemicals. These beneficial nematodes, also called entomopathogenic nematodes, are environmentally friendly alternatives to broad-spectrum chemical insecticides and are safe to humans and nontarget organisms because they only attack insects. The experiment will test the movement and behavior of beneficial nematodes in space to determine whether nematodes will be able to navigate through soil and infect insects. This will be the first biological control experiment in space and an important glimpse of the future when food crops will be grown there. (NP 304, Project No. 6042-22000-023-00D)

Improved mechanical blueberry harvesters.

Blueberry growers want to replace hand picking with machines to harvest blueberries. Current blueberry harvesting machines use hard fruit-catching plates that cause significant damage to the detached blueberries that fall on them. ARS researchers in Kearneysville, West Virginia, developed and patented durable catch plates allowing mechanical harvesters to harvest blueberries without bruise damage. In 2018, new catch plates for commercial blueberry harvesters were manufactured using the USDA patent and tested in California, Florida, Oregon, and Washington. U.S. commercial blueberry growers are now mechanically harvesting high-quality blueberries using the ARS patented design. (NP 305, Project No. 8080-21000-028-00D)

Oilseed cover crops reduce unwanted soil nitrogen loss.

Contamination of water from the leaching and runoff of labile soil nitrogen and phosphorus from corn-soybean cropping systems in the Upper Midwest is a major concern. This loss occurs mostly during fall and spring when the soil is left bare between summer crops. Winter annual cover crops can use leftover nitrogen and phosphorus from the previous crop and keep these nutrients from contaminating water. ARS researchers from Morris, Minnesota, in collaboration with University of Minnesota scientists, demonstrated that winter camelina and pennycress grown as cover crops are as effective as winter rye at using excess nitrogen and preventing its escape from agricultural systems into waterways. Scientists compared results of cultivating camelina and pennycress winter oilseeds with results from a typical no-till and conventional till system lacking a cover crop and found the two oilseed cover crops reduced soil water nitrate nitrogen losses by 84 percent and 91 percent, respectively. Camelina and pennycress also can be harvested as oilseed cash crops, adding yet more value to the system. This information will benefit growers interested in cover cropping, agricultural scientists, extension educators, and consultants, and is being used in developing new sustainable cropping systems. (NP 305, Project No. 5060-21220-006-00D)

Improved crop water use sensor for grapes.

Conserving water during crop production is an important environmental consideration for vineyard production systems. In areas with limited water supplies, efficient water use is critical for profitability. To reduce irrigation, growers need precise information on how much water grapevines need. In collaboration with University of California–Davis researchers and industry cooperators, ARS scientists in Davis, California, developed an inexpensive, stand-alone sensor that provides growers with low-cost, site-specific estimates of crop water use for scheduling irrigation. The new system is based on “surface renewal” methods that estimate plant evapotranspiration by measured and modeled energy balance

components to quantify vineyard water use. The new surface renewal method does not rely on calibration against other methods to obtain accurate measurements of plant water use. (NP 305, Project No. 2032-21220-007-00D)

Small hive beetle genome sequenced: Unique ability to detoxify pesticides revealed.

Small hive beetle eats through honey bee hive comb, honey, pollen, and brood, and is an important worldwide parasite of social bee colonies. ARS scientists in Beltsville, Maryland, sequenced and characterized the beetle genome and found it contains unique detoxification genes. In addition, sequencing described the proteins used by these beetles to identify each other and honey bee colonies by smell, a critical target for attempts to trap beetles. The study provides new insights into the genomic basis for local adaption and invasiveness in the beetle and a blueprint for control strategies that target this pest without harming their honey bee hosts. (NP 305, Project No. 8042-21000-290-00D)

Release of new plant germplasm and cultivars.

In FY 2019, ARS scientists released 41 enhanced germplasms and cultivars. Of these, 33 were publicly released and 8 (a spinach, barley, potato, broccoli, chickpea, wheatgrass, orchid grass, and tall wheat grass) are being protected through a Plant Patent or Plant Variety Protection.

The National Genetic Resources Program (NGRP).

The 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 2019, 265,704 samples were distributed to foreign genebank/resources units; international agricultural research centers; U.S. and foreign commercial companies; and U.S. and foreign agencies and universities.

Site	Samples	Accessions	Requests	Countries
National Arboretum (NA)	289	236	85	3
National Arid Land Plant Genetic Resources Unit (PARL)	519	331	44	10
National Laboratory for Genetic Resources Preservation (NSSL)	381	378	45	1
National Small Grains Collection (NSGC)	29,070	22,198	657	42
Natl. Germplasm Repository - Corvallis (COR)	7,032	3,434	704	15
Natl. Germplasm Repository - Davis (DAV)	2,898	1,318	311	10
Natl. Germplasm Repository - Geneva (GEN)	8,084	2,317	541	9
Natl. Germplasm Repository - Hilo (HILO)	170	94	36	3
Natl. Germplasm Repository - Mayaguez (MAY)	174	114	79	2
Natl. Germplasm Repository - Miami (MIA)	682	440	122	8
Natl. Germplasm Repository - Riverside (RIV)	418	256	98	9
North Central Regional PI Station (NC7)	60,703	23,025	1,398	56
Northeast Regional PI Station (NE9)	13,618	7,060	240	25
Ornamental Plant Germplasm Center (OPGC)	651	399	98	6
Plant Genetic Resources Conservation Unit, Griffin, GA (S9)	47,645	27,526	879	46
Plant Variety Protection Voucher Collection (PVPO)	4	4	1	1
Potato Germplasm Introduction Station (NR6)	6,839	1,785	202	13
Rice Genetic Stock Center (GSOR)	20,910	13,570	176	15
Soybean Collection (SOY)	21,242	9,578	514	29
US Nicotiana Germplasm Collection (TOB)	218	144	69	10
Western Regional PI Station (W6)	44,157	28,311	1,102	43
Total	**265,704**	**142,518**	**7,401**	**356**

NATIONAL AGRICULTURAL LIBARY

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 website, www.nal.usda.gov. NAL's vision is "advancing access to global information for agriculture."

Ag Data Commons and public access to digital scientific research data.

Ag Data Commons is the platform that provides public access to USDA-funded digital scientific research data. In FY 2019, the National Agricultural Library (NAL) carried out major upgrades to Ag Data Commons to meet its customer's needs for data management and access. NAL piloted ways to store and provide access to large data files in Ag Data Commons through SCINet. The Ag Data Commons continued to demonstrate its value as a key data resource for agricultural research through significant increases in all system management metrics, including registered users, unique visitors, downloads, and page views. NAL continued to gather customer perspectives on Ag Data Commons including through an agreement with a private firm that conducted an impartial environmental scan of current and potential Federal agency and land-grant university customers. Continuing strategic partnerships with ARS and National Institute of Food and Agriculture (NIFA) senior program leadership and other USDA agencies continued to improve the management of USDA-funded data. After a rigorous, Department-wide review process, NAL obtained USDA Science Council approval for the Department's first Public Access to Digital Scientific Data Policy. Ag Data Commons can be found at https://data.nal.usda.gov.

PubAg expanding quickly.

NAL makes available USDA-funded peer-reviewed literature through the PubAg platform. During FY 2019, NAL continued technical development of PubAg and aggressively built up the content of the service. In 2019, the number of citations for peer-reviewed agriculture-related scientific articles available in PubAg reached 2.6 million citations, an increase of more than 500,000 citations from FY 2018. Each article citation in PubAg includes NAL Thesaurus subject terms and a link to the full-text article if it is available from an internal NAL repository, PubMed Central, or the publisher. NAL also increased the full-text corpus that is publicly accessible through PubAg by more than 130,000 full-text articles, for a total of more than 210,000 articles. This fulfills the Department's and U.S. Government's mandate for open access to federally-funded research. PubAg can be found at https://pubag.nal.usda.gov/.

i5K Workspace.

As part of the i5K initiative, which aims to sequence and analyze the genomes of 5,000 arthropod species, the i5K Workspace was established as a website that arthropod genome researchers can use to curate, visualize, and share data. The i5K Workspace now contains 72 arthropod genome assemblies and related datasets. In FY 2019, the Workspace added 3 new organisms, 24 new data sets, and 98,435 new gene pages (or gene features). NAL worked with data providers to generate three Official Gene Sets via NAL's in-house pipeline and submitted these and four additional datasets to the National Center for Biotechnology Information. The number of publications citing the work of the i5K Workspace and thus now promoting it now totals 67 (up from 45 in 2018). Reporting metrics are available at https://i5k.nal.usda.gov/i5k-workspacenal-reporting-metrics.

USDA Food Composition Database and Food Data Central.

In collaboration with the ARS Beltsville Human Nutrition Research Center and major industry partners, NAL makes available nutrition information for scientific researchers, dieticians and nutritionists, application developers, and consumers. In FY 2019 NAL hosted and made available online more than 560,000 different foods with more than 8.6 million food nutrient entries in both data products. Combined, these data products generated more than 30 million page views via 4 million user sessions. Most impressively, application developers made nearly 265 million Application Programmer Interface (API) calls against these two data products in FY 2019, making the USDA Food Composition Database and FoodData Central APIs among the most popular in government.

NAL mass digitization continues.

To make the content of the world's largest agricultural library more accessible for scientific and other forms of research, NAL is digitizing its physical collections not under copyright protection. In fiscal 2019, NAL digitized and created citation information for 13,110 items (930,432 pages), bringing total number of digitized items to 160,985 (7,692,074 pages). During FY 2019, NAL digitization continued to focus on historic USDA-issued publications, nursery and seed trade catalogs, and topic-specific content to support NAL online exhibits and information. NAL also initiated a major project to digitize the USDA legislative histories maintained by the Office of General Counsel to support the national agricultural law partnership. NAL continued contributing rare and historical titles to the Biodiversity Heritage Library. Until all mass-digitized publications are migrated to NAL web services, public access is available at https://archive.org/details/usdanationalagriculturallibrary.

3.7. Outreach Activities: Workshops, Field Days, Trainings/Demonstrations, and Stakeholder Presentations/Meetings

AL	Soil Dynamics Research	Presentation on how cover crops and irrigation can work together to improve production for growers at Alabama Extension sponsored field day "Irrigation Technologies in Your Hands."
AL	Soil Dynamics Research	Co-organized the 2019 Southern Cover Crop Council meeting held in Auburn, AL. The conference consisted of 10 sessions led by experts, a poster session, and a ½ day field tour to showcase various aspects related to cover crops.
AL	Soil Dynamics Research	Presentation on soil compaction differences following winter stocker grazing as part of determining how grazing cover crops affects soil health at an Alabama Agricultural Experiment Station sponsored field day.
AL	Soil Dynamics Research	Presented an on-demand webinar about cover crop management considerations in the Southeast. The webinar is available at the Plant Management Network website under the Focus on Cotton webcasts tab.
AR	Harry Dupree Stuttgart National Aquaculture Research Center	Presentation on the proper procedures for biosecurity in aquaculture facilities and on research on peracetic acid as a new disinfectant for biosecurity at the Fish Farms Biosecurity Workshop at the Centro De Formacion Agroindustrial La Angostura (La Angostura Agroindustrial Training Center) in Campoalegre, Huila Department, Colombia. Attended by 60 trade school apprentices and students, aquaculture coordinators and farmers.

AR	Poultry Production and Safety Research	Presented at the "Farm Foundations: Planning for Success, Beginning Farmer Livestock Workshop." This workshop provide more than 25 beginning farmers with information on pasture management, animal health, and the business and marketing aspects of small farming.
AR	Poultry Production and Safety Research	Held World Geographical Information Systems (GIS) Day at the University of Arkansas campus. This event is internationally recognized and promotes GIS technology and its applications. GIS day is an "open house" based forum and showcased a series of presentations to student, faculty, staff, and stakeholders on current research and community developments using GIS. Approximately 60 attendees participated and attended in this event.
AR	Poultry Production and Safety Research	Hosted the Armed to Farm Bootcamp. There were more than 20 veterans and or spouses present for the week-long workshop/training program. Veterans learned about a variety of farming topics from local experts in classroom sessions and went out each day to local farms to engage in hands-on learning.
AZ	Water Management and Conservation Research	Presentations to farmers, farm consultants, and farm workers on practical information for improving farm management practices at the Yuma, Arizona Southwest Ag Summit. Topics included recommended practices for water and nutrient management for cotton crops, updated reporting on crop water use by lettuce and wheat, and opportunities for improved wastewater reuse.
CA	Agricultural Water Efficiency and Salinity Research	Presented research results on "Salt Tolerance of Almond Rootstocks" at the 2018 Almond Conference. These were second-year results on screening almond rootstocks for tolerance to salinity.
CA	Commodity and Protection and Quality Research	Presentation on ARS research at Mid Valley Nut Conference.
CA	Commodity and Protection and Quality Research	Several presentations to multiple stakeholders about control of navel orangeworm in tree nuts.
CA	Crop Diseases, Pests, and Genetics Research	Hosted eight Ukraine professionals and two faculty members from California State University-Fresno who participated in the 2018 Faculty Exchange Program, Agricultural Economics, Ukraine.

CA	Invasive Species and Pollinator Heath Research	Presentation on "Biological Control of Terrestrial Weeds of Non-Crop Areas" to about 80 pesticide applicators, Professional Crop Advisors (PCAs) and local invasive weed and natural resource managers as part of a Pesticide Applicators Professional Association Seminar. The presentation included coverage of biocontrol success stories and current projects.
CA	Invasive Species and Pollinator Heath Research	Presentation on "Plant Physiology and Weed Control" for the East Bay Municipal Utility District 2019 Integrated Pest Management Workshop.
CA	Invasive Species and Pollinator Heath Research	Presentation on "What's New in Aquatic Weed Control?" for the 2019 Wildlands Integrated Pest Management Seminar. The 2-day seminar trains approximately 200 natural area land managers and was sponsored by the California Department of Fish and Wildlife.
CA	Invasive Species and Pollinator Heath Research	Presentation on "An Overview of Aquatic Weed Management" at the University of California Weed Science School. Weed Science School provides continuing education credits to certified crop advisors and qualified applicators for all of weed science areas, including crop and non-crop applications. The school is hosted by the University of California Weed Research and Information Center.
CO	Central Plains Resources Management Research	Central Great Plains Research Station hosted a Field Day event for the local farming community. The all-day event included presentations on dry-land crop experiments and soil research findings conducted the past year.
CO	Central Plains Resources Management Research	Organized a workshop on soil health in the west at Adams State University. This was an educational workshop held to benefit small farms research and conservation efforts throughout the country. Researchers, students and farmers were included in those in attendance.
DC	Floral and Nursery Plants Research	Set up a series of demonstrations and "show and tell" exhibits at the U.S. National Arboretum to showcase ARS research impact to attendees of the annual meeting of the American Public Garden Association.
DC	Floral and Nursery Plants Research	The Nursery Crops Research Station in McMinnville, TN hosted local nursery producers and industry specialists for research tours and presentations.
DC	Floral and Nursery Plants Research	Participated in the Plant Collections Consortium of the American Public Gardens Association. This group is composed of member gardens from across the U.S. who are engaged in plant germplasm collection and conservation.

DC	Floral and Nursery Plants Research	Participated in a webinar on boxwood blight research hosted by AmericanHort.
DC	Floral and Nursery Plants Research	Presentation on "The value of germplasm collection, breeding, and genetic resources using *Prunus* as a model" at the annual meeting of the American Public Gardens Association.
DC	Floral and Nursery Plants Research	Presentation on "*Fraxinus* diversity and emerald ash borer: delineating species, engaging citizen scientists" at the annual meeting of the Society of American Foresters.
DC	Floral and Nursery Plants Research	Presentation on "The U.S. National Arboretum: using science - improving landscapes" at the Philadelphia Flower Show.
DC	Floral and Nursery Plants Research	Multiple presentations on "Woody landscape plant selection and identification" to the District of Columbia Master Gardeners and the Montgomery County Master Gardeners.
DC	Floral and Nursery Plants Research	Presentation on "Genetic diversity of cultivated *Hydrangea* using genotyping-by-sequencing (GBS)" at the 63rd Annual Southern Nursery Association Research Conference.
DC	Floral and Nursery Plants Research	Presentation on hydrangea breeding at a University of Tennessee workshop on "The A to Z of Producing Excellent Hydrangeas."
DC	Gardens Unit	Demonstrated bonsai cultivation techniques at the U.S. National Arboretum on World Bonsai Day to approximately 100 visitors.
DC	Gardens Unit	Presentation on "What's new with Hydrangeas and Magnolias?" at the Spring into Spring Master Gardner Conference.
DC	Gardens Unit	Presentation on "Selecting and planting trees for success" for the Green Spring Gardens meeting.
DC	Gardens Unit	Presentation on plant biodiversity to the Montgomery County (Maryland) Master Gardeners.
DC	U.S. National Arboretum	Participated in the annual meeting of the American Public Gardens Association, which included presentations at the meeting and hosting tours, meetings, and a dinner at the U.S. National Arboretum.
DC	U.S. National Arboretum	Presentation on "Collections breed success at the National Arboretum" at the Morris Arboretum.
DC	U.S. National Arboretum	Presentation on "From the Ground Up: Keeping horticulture alive through grounds and infrastructure management" at an American Public Garden Association Symposium.

DC	U.S. National Arboretum	Presentation on "Cackalacky® connections: the impact of North Carolina gardeners at the National Arboretum" at the North Carolina Master Gardener 40th Anniversary Lecture.
FL	Invasive Plant Research	Presentation to Broward County (Florida) residents on aspects of water and environment conservation.
FL	Invasive Plant Research	Presentation to landscape practitioners on biological control.
GA	Peanut Research	In collaboration with University of Georgia (UGA) engineers, conducted training sessions for UGA County Extension Agents on the use of Irrigator Pro mobile application for scheduling irrigation for cotton and peanuts.
GA	Peanut Research	Presentation on peanut introgression and pre-breeding at the National Peanut Board's symposium on "The Future of Precision Peanut Breeding."
GA	Peanut Research	Conducted training on good management practices for storing farmers stock peanuts to peanut warehouse managers, maintenance personnel, fumigation teams, procurement managers at the Integrated Pest Management (IPM) Workshop sponsored by the Food Safety and Sanitation Committee of the American Peanut Shellers Association.
GA	Plant Genetics Resources Conservation Research	Presentation on the National Plant Germplasm System and perennial peanut collection at the "Perennial Peanut Field Day" at the University of Florida-North Florida Education and Research Center.
GA	Poultry Microbiological Safety and Processing Research	Participated in the International Poultry Production Exposition.
IA	Agroecosystems Management Research	Demonstrateion of an Agricultural Conservation Planning Framework storymap, a website providing online access to field-specific conservation practice placement options, at the North Central Iowa Crop and Land Stewardship Clinic hosted by Iowa State University Extension.
IA	National Laboratory for Agriculture and the Environment	Presentation on the pathway to improving soil through the use of soil biology to Regenerative Agriculture and Gardening Workshop.
IA	National Laboratory for Agriculture and the Environment	Delivered the Sidore Lecture at Plymouth State College on the impact of climate change on agriculture and the implications for future food security.

IA	National Laboratory for Agriculture and the Environment	Presented the keynote address "Weather-Proofing Your Cropping System" at the Profitable Farming in a Changing Climate workshop sponsored by USDA-NRCS, Minnesota Department of Agriculture, Sustainable Agriculture Research and Education (SARE), and soil water conservation districts in Southern Minnesota.
IA	National Laboratory for Agriculture and the Environment	Presentation on "Fertilizer and Manure Nutrient Management with Cover Crops to Improve Impacts on Water Quality" at the Clinton County (Illinois) Cover Crop Field Day.
IA	National Laboratory for Agriculture and the Environment	Presented the keynote address "Systems Approach to Improve Soil Health, Agro-economics, and Environmental Services" to the 2019 Soil Health Conference.
IA	National Laboratory for Agriculture and The Environment	Presented a keynote address "Agriculture Practices and the Weather" at the Lake Springfield, Illinois Watershed Reduced Tillage and Cover Crops Meeting.
IA	National Laboratory for Agriculture and The Environment	Presentation on "Weeds in Iowa: What will change?" at the annual meeting of Iowa Weed Commissioners.
IA	Plant Introduction Research	Participated in a podcast hosted by the University of Minnesota Urban Forestry Outreach, Research & Extension program "Episode 3: Mad about Kentucky Coffeetrees" which explained the mission of the National Plant Germplasm System with detailed discussions on the efforts to collect Kentucky coffeetree germplasm throughout the species native range.
IA	Soil, Water, and Air Resources Research	Multiple presentations on the nature of humic products as biostimulants at annual meeting of the Humic Products Trade Association, a network of crop consultants, Ontario Fruit and Vegetable Convention, and for Ag Logic Distributors.
ID	Range Sheep Production Efficiency Research	Presented a webinar "Getting the Most Out of Your Vaccination Program" hosted by the American Sheep Industry Association. Registrants were from 46 U.S. states, six provinces of Canada, and three countries. After the webinar, approximately 20 webinar participants contacted the ARS location for further guidance on vaccinations programs for sheep.
KY	Forage-Animal Production Research	Participated in the 2019 "Annual Beef Bash" hosted by the University of Kentucky with a forage research presentation and tour stop.

LA	Sugarcane Research	Hosted the 2019 LSU AgCenter Terrebonne/Lafourche Parish Field Day. The field day showcased research on sugarcane variety development, weed control technology, precision agriculture, and billet planting cultural practices.
LA	Sugarcane Research	Presentation on cover crops and soil compaction at Louisiana State University's 2019 Iberia/Vermilion/St. Mary Sugarcane Field Day.
LA	Sugarcane Research	Presented research on "Billet Planting" at the 50th Annual Assumption Parish Sugarcane Field Day.
MD	Animal Genomics and Improvement Laboratory	Presentation on identifying the optimal test period to estimate feed efficiency using residual feed intake in dairy cattle to Select Sires, Inc. and other dairy industry stakeholders.
MD	Animal Production and Protection National Program	Presentation on transboundary animal diseases and defense research at Kansas State University's "BSL-3 (biosafety level) Summer Training Program."
MD	Animal Production and Protection National Program	Met with stakeholders from the Maryland Eastern Shore to discuss the issues and challenges facing oyster aquaculture in the Chesapeake Bay, including areas where ARS research programs could provide assistance, with an emphasis on genetic improvement.
MD	Animal Production and Protection National Program	Participated in the National Institute for Animal Agriculture Antibiotic Symposium. Presented an update of ARS research programs. Meeting attendees included other federal agencies, livestock and pharmaceutical industries, and state and local animal health officials.
MD	Animal Production and Protection National Program	Hosted the National Bio and Agro-Defense Facility (NBAF) Stakeholders and Partnerships Conference and gave presentations on ARS animal health research programs.
MD	Animal Production and Protection National Program	Participated in the Keep Antibiotics Working Coalition group meeting to discuss alternatives to antibiotics and antimicrobial resistance research.
MD	Animal Production and Protection National Program	Presentation on "Overview of USDA/ARS Veterinary, Medical, and Urban Entomology Program" at the Vector Management Workshop, sponsored by the Taiwan Pest Control Association and Asian Society of Vector Ecology.
MD	Animal Production and Protection National Program	Presentation on "Potential for New Genetics Techniques to Enhance Catfish Production" at the Catfish Farmers of America Annual Convention.
MD	Animal Production and Protection National Program	Participated in the National Pork Board, National Pork Producers Council, and the American Association of Swine Veterinarians Meeting and presented information on ARS research programs.

MD	Animal Production and Protection National Program	Presentation on "Research Priorities and the Implementation of Prevention and Control Measures in the United States" at the African Swine Fever (ASF) Workshop.
MD	Crop Production and Protection National Program	Met with members of the National Barley Growers Association to discuss their 2019 research needs and policy priorities for the U.S. Wheat & Barley Scab Initiative and Small Grains Genomic Initiative.
MD	Crop Production and Protection National Program	Met with Washington State Potato Council members to update ARS research activities.
MD	Crop Production and Protection National Program	Co-led trilateral workshop with Mexico and Canada on topics related to plant viruses and vector-borne viruses of crops of interest to all three countries.
MD	National Agricultural Library Digitization and Access Branch	Highlighted Special Collections and National Agricultural Library Materials with the Reference and the Food and Nutrition Information Center at the USDA Farmers Market.
MD	National Agricultural Library Digitization and Access Branch	Presented Special Collections materials for the USDA History Wikipedia Edit-a-thon and assisted wikimedians with resources.
MD	National Agricultural Library Information and Customer Services Branch	Multiple demonstrations to many stakeholder groups of DigiTop and other NAL services and resources.
MD	National Agricultural Library Information and Customer Services Branch	Conducted training on searching and retrieving information using the Business Source Premier database.
MD	National Agricultural Library Information and Customer Services Branch	Multiple demonstrations to many stakeholder groups of the iThenticate anti-plagiarism software which compares manuscripts with published documents.
MD	National Agricultural Library Information and Customer Services Branch	Conducted training for librarians on NAL services and resources from behind the scene.
MD	National Agricultural Library Information and Customer Services Branch	Conducted training of SAGE Research Methods database for DigiTop Liaisons and library staff.
MD	National Agricultural Library Information and Customer Services Branch	Demonstration of the National Invasive Species Information Center website and other information services to APHIS employees.
MD	National Agricultural Library Information and Customer Services Branch	Presented an exhibit booth at the 2019 Annual Agriculture Outlook Forum with information on and demonstrations of resources and services available from the library.

MD	National Agricultural Library Information and Customer Services Branch	Provided a webinar to the Department of Defense on literature searches and the history of the Animal Welfare Act.
MD	Natural Resources and Sustainable Agricultural Systems National Program	Participated in Soil Health Champion "Coffee" at the National Association of Conservations Districts.
MD	Nutrition, Food Safety, and Food Quality National Program	Discussed ARS research on innovative new uses of corn with the National Corn Growers Association Board.
MD	Nutrition, Food Safety, and Food Quality National Program	Discussed ARS research on innovative new uses of soft wheat with the wheat quality council, Eastern wheat workers, and Southern small grain workers.
MD	Nutrition, Food Safety, and Food Quality National Program	Discussed Nutrition, Food Safety and Quality Research Program accomplishments to university and industry stakeholders.
MD	Nutrition, Food Safety, and Food Quality National Program	Gave a presentation to PNC Bank agricultural leaders on ARS research on innovative new uses of food, fibers, and biorefining.
MD	Nutrition, Food Safety, and Food Quality National Program	Presentation to Dow Chem, Corning Glass, and Sherwin/Williams representatives on ARS research on innovative new uses of food, fibers, and biorefining.
MD	Nutrition, Food Safety, and Food Quality National Program	Participated in a University of Mississippi workshop on natural products to combat microbial resistance.
MD	Office of Associate Administrator	Participated in the National Alfalfa and Forage Alliance board meeting with farmers, industry and university partners.
MD	Office of Technology Transfer	Hosted a webinar on a "Farmer Round Table Discussion: Organic Row Crop Production."
MD	Office of Technology Transfer	Participated in the annual meeting of the National Association for Community College Entrepreneurship providing information on ARS research and technologies available for licensing.
MD	Office of Technology Transfer	Participated in the annual meeting Maryland Technology Development Corporation (TEDCO) providing information on ARS research and technologies available for licensing.
MD	Office of Technology Transfer	Participated in the "Lower Shore Maryland Industry Day" providing information on ARS research and technologies available for licensing.
MD	Office of Technology Transfer	Participated in the "Upper Shore Maryland Industry Day" providing information on ARS research and technologies available for licensing.

MD	Office of Technology Transfer	Participated in the annual meeting of RuralRise providing information on ARS research and technologies available for licensing.
MD	Office of Technology Transfer	Participated in SBIR Roadshow to Northeast providing information on ARS research and technologies available for licensing.
MD	National Agricultural Library	Presentation at the Federal Depository Library Program (FDLP) Conference on services and resources available from NAL.
MD	National Agricultural Library	Held an open house to celebrate the 50th Anniversary of the NAL at its current location on the Henry A. Wallace Beltsville Agricultural Research Center campus.
MD	National Agricultural Library	Participated in a webinar on "Open Data and the Ag Data Commons" hosted by Auburn University.
MD	National Agricultural Library Scientific Data Management Branch	Hosted a training webinar on the i5k Workspace to introduce users to the concepts of manual annotation and the Apollo software.
MD	National Agricultural Library Scientific Data Management Branch	Held a workshop on the process of manual annotation and the Apollo software at 2019 Arthropod Genomics Symposium.
ME	National Cold Water Marine Aquaculture Center	Hosted the Maine Hatchery Roundtable which focused on spawning and included invited speaker discussing genomic selection tools and how they are implemented in fish breeding programs such as the catfish program, sterilization techniques, cryopreservation of milt and review of spawning techniques.
MI	Sugarbeet and Bean Research	Participated in the Saginaw Valley Research and Extension Center's annual field day presenting ongoing research efforts and disease issues in the region.
MN	Soil and Water Management Research	Presented research on how denitrifying bioreactors can reduce agricultural drainage nitrate losses at a Soil and Water Conservation District meeting. Attendees included consulting engineer, contractor, and industry personnel.
MN	Soil and Water Management Research	Presentation on the impact of biochar on soil moisture interactions and magnetic field effects at the Intensive Biochar Workshop.
MN	Soil and Water Management Research	Presentation on soil health and testing options that can assist non-operating landowners in discussing management options with renters at "Digging Deeper: Managing for Stewardship Workshop".
MS	Cotton Ginning Research	Tour and demonstration of microgin to retired textile industry researchers.
MS	Cotton Ginning Research	Hosted a research tour for the 2019 American Cotton Shippers Association International Cotton Institute.

MS	Crop Genetics Research	Interviewed in a video for the Mississippi Soybean Promotion Board that highlighted research on mature seed damage and heat tolerance in soybean.
MS	Southern Horticultural Research	Held "Blueberry Field Day" for current growers and potential growers.
MT	Agricultural Systems Research	Hosted a joint Federal and State "Dryland Field Day."
MT	Agricultural Systems Research	Participated in the "Froid Field Day with on presentations on weed ID, weed management, and biocontrol.
MT	Range and Livestock Research	Held the Annual Customer Focus Group to discuss current research and what research would be useful in the future.
MT	Range and Livestock Research	Presentation on "Water mineral content: How important is it to cattle mineral nutrition and well-being?" to the public during two separate workshops.
NE	Office of the Director	Hosted the Beef Focus Group meeting. Presentations were given on current research and discussions took place to determine the best course of action moving forward. Input from stakeholders was received.
NM	Cottoning Ginning Research	Provided a ginning demonstration at the New Mexico State Fair.
NM	Cottoning Ginning Research	Hosted eight Cochran Fellows from Malawi as part of a New Mexico State University sponsored workshop for a gin tour and presentation on cotton and ARS research.
NM	Range Management Research	Workshop and field training of the Assessment Inventory Monitoring (AIM).
NM	Range Management Research	Provided training on brush monitoring training to technical service providers.
NM	Range Management Research	Provided training on climate CoCoAH to the Navajo Nation Farm Board.
NM	Range Management Research	Participated in the New Mexico NRCS "Prescribed Grazing Workshop."
NM	Range Management Research	Participated in the Ecological Side Description (ESD) State Group Meeting.
NM	Range Management Research	Hosted the 2019 Interpreting Indicators of Rangeland Health workshop.
NM	Range Management Research	Presentation on "Interpreting and Measuring Indicators of Rangeland Health" for Bureau of Land Management, NRCS, U.S. Forest Service employees, university students, and international visiting scientists.
NM	Range Management Research	Participated in the Jornada Field Botany Workshop attended by university faculty and the local community.

NY	Emerging Pests and Pathogens Research	Participated in the NY State Farm Show with a booth highlighting ARS research and hands-on insect exhibits.
OH	Application Technology Research	Presentation and demonstration on "Intelligent Sprayer Technologies to Improve Pesticide Application Efficiency in Orchards" at the Intelligent Spray Technologies and Systems Workshop organized by Penn State Fruit Research and Extension Center.
OH	Application Technology Research	Multiple presentations on "Ambrosia Beetle: Identification, Biology, Behavior, Monitoring, and Management" at the Bartlett Tree Experts & Old Westbury Gardens Annual Horticultural Forum and Annual Meeting of the Virginia Nursery and Landscape Association.
OH	Application Technology Research	Presentation on "Perfecting your pour-through procedure" to leading greenhouse growers and allied industry members at the Floriculture Research Alliance annual meeting.
OH	Application Technology Research	Met with Northwest Ohio horticultural producers to discuss horticultural research initiatives and present the next 5 years of research objectives.
OH	Application Technology Research	Presentation on "Selecting silicon amendments for soilless substrates" to leading greenhouse growers and allied industry members at the Floriculture Research Alliance annual meeting.
OH	Corn, Soybean, and Wheat Quality Research	Met with the Ohio Corn & Wheat Growers Association, Ohio Corn Marketing Program and Ohio Small Grains Marketing Program. Discussions were held one-on-one and in small groups regarding ARS research.
OH	Corn, Soybean, and Wheat Quality Research	Presentation of results on wheat virus resistance testing a diversity panel of soft red winter wheat to the Ohio Small Grains Marketing Program board.
OH	Soil Drainage Research	Presented on the importance and basic techniques for conducting ecological evaluations of the effects of conservation practices on fishes within agricultural streams at a field day held within the Upper Big Walnut Creek.
OH	Soil Drainage Research	Invited participant at the Woolpert Client Panel Discussion III with approximately 20 participants (industry and government) from across the country who met to discuss needs and issues related to aerial/satellite imagery and geographic information systems.
OH	Soil Drainage Research	Participated in the 2019 Conservation Tillage and Technology Conference and presented research on "UAVs as a Tool for Tile Mapping."
OH	Soil Drainage Research	Presented ongoing science and research on water quality to fertilizer industry representatives at the Fertilizer Outlook Technology Conference.
OH	Soil Drainage Research	Presented water quality findings from the USDA-ARS Edge-of-field Network to multiple groups, including NRCS, Ohio

		Farm Bureau, Pennsylvania Farm Bureau, Seneca County Conservation District, 4R Summit, Ohio State University (OSU) Agronomic Field Day, OSU Precision Agriculture Workshop, Harmful Algal Blooms State of the Science Conference, and AG Solutions annual meeting.
OH	Soil Drainage Research	Presentation on "Effects of Manipulating Ca:Mg Ratios on Ohio Crop Yields and Soil Health" at the Conservation Tillage and Technology Conference.
OK	El Reno Research Center	Co-hosted with Sure Crop Fertilizer, NRCS, Oklahoma Association of Conservation Districts and Oklahoma Land Stewardship Alliance a Central Oklahoma Soil Health Seminar to facilitate soil health outreach activities to regional producers and agriculture professionals.
OK	Great Plains Agroclimate and Natural Resources Research	Hosted the International Agroecosystems Living Laboratories working group. Working group includes representatives from 12 countries, under the auspices of the G-20. Presented Long-Term Agroecosystem Research (LTAR) research activities.
OK	Great Plains Agroclimate and Natural Resources Research	Organized the "Wildfire Suppression Through Prescribed Fire Workshop" in partnership with NRCS, Oklahoma Cooperative Extension and the Cheyenne & Arapaho Tribes. Eighteen fire departments from across Oklahoma participated.
OK	Great Plains Agroclimate and Natural Resources Research	Hosted the 2019 High Plains Technical Workshop on Drought Monitoring. The workshop included 25 attendees from 8 states who collectively identified a set of science and services recommendations to improve drought monitoring and impact reporting in the High Plains region.
OK	Hydraulic Engineering Research	Participated in Oklahoma NRCSmeeting to discuss ARS stepped spillway design criteria.
OK	Hydraulic Engineering Research	Participated in National Dam Safety Review Board and Interagency Committee on Dams Meeting.
OK	Hydraulic Engineering Research	Participation in the Oklahoma Water Resources Center Advisory Board Meeting.
OK	Hydraulic Engineering Research	Exhibited at the Oklahoma Association of Conservation Districts Annual State Meeting. Interacted with stakeholders and provide information on current research.
OK	Hydraulic Engineering Research	Presentation at the University of Oklahoma's Water Day.
OK	Hydraulic Engineering Research	Presentation and host of the NRCS Oklahoma Engineering and Conservation Engineering Technician Meeting.
OK	Hydraulic Engineering Research	Presentation on dam research to the Federal Emergency Management Agency (FEMA) National Interagency Committee.

OK	Hydraulic Engineering Research	Hosted the Oklahoma NRCS Conservation Book Camp with field presentations.
OK	Hydraulic Engineering Research	Presentation at the U.S. Army Corps of Engineers Hydraulic Structures Workshop.
OK	Rangeland and Pasture Research	Co-hosted with the Oklahoma State Extension Service "Range Research Field Day" with presentations on using wheat pasture in a cow/calf enterprise; new technologies for measuring efficiency of beef cattle; soil and vegetation change from 75+ years of no grazing or fire'; and other topics.
OK	Rangeland and Pasture Research	Held the annual "Chilcott Conference/Stakeholder Meeting."
OK	Rangeland and Pasture Research	Participated in the Northwest Oklahoma Cattleman's Foundation trade show and presented information on ARS research.
OK	Rangeland and Pasture Research	Presentations at the 5-State Beef Conference to producers on current research.
OK	Rangeland and Pasture Research	Presentation on mineral supplementation of growing cattle grazing wheat pastures at the Oklahoma State University's Marshall Wheat Pasture Research Unit Field Day.
OR	Horticultural Crops Research	Held training on the grapevine red blotch loop-mediated isothermal amplification (LAMP) reaction detection method.
OR	Horticultural Crops Research	Presentation on alternative management strategy for spotted wing drosophila for OR and WA blueberry growers at an Oregon State University field day.
OR	Horticultural Crops Research	Met separately with the Oregon Blueberry Commission and the Washington Blueberry Commission to discuss ARS research and stakeholder needs.
OR	Horticultural Crops Research	Met with stakeholder to discuss management of gray mold disease with fungicides and shelters.
OR	Horticultural Crops Research	Presentation at Washington Red Raspberry Commission to discuss ARS research and stakeholder needs.
OR	Horticultural Crops Research	Met with stakeholders to plan research on management of mummy berry disease of blueberry in organic production systems.
OR	Horticultural Crops Research	Met with stakeholders to discuss research on the control of crown gall in blueberry.
OR	Horticultural Crops Research	Met with stakeholders to examine outbreak of cane diseases of blackberry and discuss research approaches.

OR	Horticultural Crops Research	Participated in the Oregon Wine Symposium and Grape Industry Meeting to discuss grape quarantine and certification changes proposed for the Pacific Northwest as part of Clean Plant Program.
OR	Horticultural Crops Research	Participated in the Willamette Valley Grape Growers meeting to discuss Grapevine Red Blotch Virus.
OR	Horticultural Crops Research	Met with stakeholders to discuss virus complexes in blueberry and increased disease severity.
OR	Horticultural Crops Research	Participated in the Oregon Association of Nurseries meeting to discuss research interests and concerns of Oregon's boxwood nursery industry regarding boxwood blight.
OR	Horticultural Crops Research	Presentation on future technology advances in viticulture to the California Association of Winegrape Growers.
OR	Horticultural Crops Research	Presentation on fungicide resistance at Oregon Raspberry and Blackberry Growers Annual Meeting.
OR	Horticultural Crops Research	Presentation on Red Blotch epidemiology at Oregon State University's Extension's Grapevine Red Blotch Workshop.
OR	Horticultural Crops Research	Presentation about risks of fungicide resistance and spread of soilborne pathogens in the nursery industry at an ornamental workshop.
OR	Horticultural Crops Research	Presentation about management alternatives for spotted wing drosophila at Cherry Day for cherry growers in OR and WA.
OR	National Clonal Germplasm Repository	Hosted the curator for the Chinese strawberry collection from Beijing Academy of Forestry and Pomology Sciences for a 3 -month study on strawberry conservation techniques.
PA	Pasture Systems and Watershed Management Research	Participated in the Pennsylvania Ag Progress Days. Ag Progress Days is a three-day educational outreach event held in Centre County, PA that is attended by approximately 46,000 producers and the general public. ARS exhibits featured riparian management options; inter-seeding cover crops for early establishment; the MAPHEX (MAnure PHosphorus EXtraction) Manure Treatment System; and the location' participation in the Long-Term Agroecosystem Research network and the Northeast Climate Hub.
PR	Tropical Crops and Germplasm Research	Hosted a group of teachers to learn more about tissue culture techniques. The group is part of a NASA project subcontracted through the Fairchild Tropical Botanic Gardens where they are doing research on the Space Veggies program or Growing Beyond Earth (GBE), in order to provide astronauts with the right kind of veggies which can be grown in small greenhouses in their flight cabins.

SC	Coastal Plain Soil, Water and Plant Conservation Research	Held the annual Customer/Partner Dialogue Workshop. Approximately 60 stakeholders from academia, federal agencies, industry, commodity groups, and farmers attended. Stakeholders spent time with individual scientists discussing research findings, and formal presentations were made pertaining to new research on soybean and cotton enhancement productivity with lower environmental impact.
TX	Grassland, Soil, and Water Research	Presentation on ARS oats, wheat, and barley trials at the "Bell County Central Texas Small Grain Field Day."
UT	Forage and Range Research	Participated in the "Upper Sevier Watershed Tour and Utah State University Pasture Walk."
UT	Forage and Range Research	Participated in stakeholder meeting presenting research on perennial agriculture.
UT	Forage and Range Research	Participated in the Central Utah Grazing Expo.
UT	Poisonous Plants Research	Presented information on poisonous plants to stakeholders and disseminated USDA Poisonous Plant Bulletin 415.
UT	Poisonous Plants Research	Hosted a booth at the Society for Range Management Meeting to answer questions and discuss poisonous plants.
WA	Physiology and Pathology of Tree Fruit Research	Participated in field day at the Washington State University Tree Fruit Research and Extension Center's Sunrise research orchard. Discussed ongoing research characterizing apple fruit maturation with stakeholders, research, and extension personnel.
WA	Physiology and Pathology of Tree Fruit Research	Multiple presentations on apple and pear fruit postharvest management with growers and warehouse personnel from Washington state, Pacific Northwest Pear Committee Research Review, and a group of growers and research personnel from Tajikistan.
WA	Wheat Health, Genetics, and Quality Research	Presentation on "Diversifying the Wheat Portfolio of the Pacific Northwest" as part of the 2018 Washington State University Wheat Academy. Topics included variety development, Asian noodles, waxy wheat cereal, and soft kernel Durum wheat.
WV	Innovative Fruit Production, Improvement, and Protection	Assisted in WVU Extension and Berkeley and Jefferson County Master Gardeners Tomato Fest.
WV	Innovative Fruit Production, Improvement, and Protection	Met with growers and industry representatives from at least five states and programs to learn about the research programs and advances at the Appalachian Fruit Research Station.
WV	Innovative Fruit Production, Improvement, and Protection	Presented a webinar "Transforming Pixels to Millimeters: Geometric Camera Calibration" hosted by the American Society of Plant Biologists.

WV	Innovative Fruit Production, Improvement, and Protection	Presentation to the Young Growers Alliance at the mid-Atlantic Fruit and Vegetables Convention and discussed mechanisms for sustainability managing invasive species.
WV	Innovative Fruit Production, Improvement, and Protection	Presentation on how to manage brown marmorated stink bug to approximately 50 fruit growers in Connecticut.
WV	Innovative Fruit Production, Improvement, and Protection	Presented several workshops at the 167th Air Guard Base on fruit tree pruning; planting and care of fruit trees; care and maintenance of small fruit crops; and grafting of apple trees using different budding techniques as part of the Patriot Gardens program. This program is intended to get veterans involved or interested in agricultural enterprises.
WV	Innovative Fruit Production, Improvement, and Protection	Presentation on how to manage invasive pests in fruit trees at a Utah State University growers workshop.
WV	Innovative Fruit Production, Improvement, and Protection	Held a workshop on summer pruning of blackberries at Virginia Tech Cooperative Extension Service Twilight Meeting.
WV	Innovative Fruit Production, Improvement, and Protection	Held a field tour to celebrate the 40th Anniversary of the Appalachian Fruit Research Station. More than 100 grower and stakeholder visitors from at least five states and programs toured field plots and learned about ARS research.

3.8. FY 2019 Technology Transfer Award Winners

ARS Technology Transfer Award

Scientist: *Judson V. Edwards*

Title: For development of a cotton-based wound dressing resulting in a commercial product used for battlefield and emergency response applications to trauma.

Federal Laboratory Consortium for Technology Transfer (FLC) Awards (note: the Midwest, Southeast, Far West, and Mid-Continent Regions did not have awards in FY 2019. They moved their FY 2019 Summer meetings to the Fall of the FY 2020).

Laboratory: Meat Animal Research Center

Title: Novel Sampling Methods for Beef Trim Pathogen Testing

Award: National, Excellence in Technology Transfer

Person: James A. Poulos, III

Award: National, Outstanding Technology Transfer Professional

Laboratory: Food Safety and Intervention Technologies Research and Princeton Plasma Physics Laboratory, MD and NJ

Title: Radio Frequency Pasteurization of Shell Eggs

Award: Northeast Region, Excellence in Technology Transfer

Laboratory: National Cold Water Marine Aquaculture Center, ME

Title: Genetic Improvement of Germplasm for the U.S. Atlantic Salmon Industry

Award: Mid-Atlantic Region, Excellence in Technology Transfer

Laboratory: Genetic Improvement for Fruits and Vegetables Laboratory, MD

Title: Pepper Jack, Midnight Creeper & Lil' Pumpkin

Award: Mid-Atlantic Region, Excellence in Technology Transfer

Laboratory: Plum Island Animal Disease Center, NY

Title: A Cell Line Sensitive to Foot and Mouth Disease Virus

Award: Mid-Atlantic Region, Excellence in Technology Transfer

Laboratory: Office of Technology Transfer and NIFA-SBIR Program, MD

Title: SBIR-Technology Transfer Program

Award: Mid-Atlantic Region, Interagency Partnership

Person: James A. Poulos, III

Award: Mid-Atlantic Region, Outstanding Technology Transfer Professional

3.9. Selected Metric Charts.

Figure 1. Number of new and active CRADAs and MTRAs

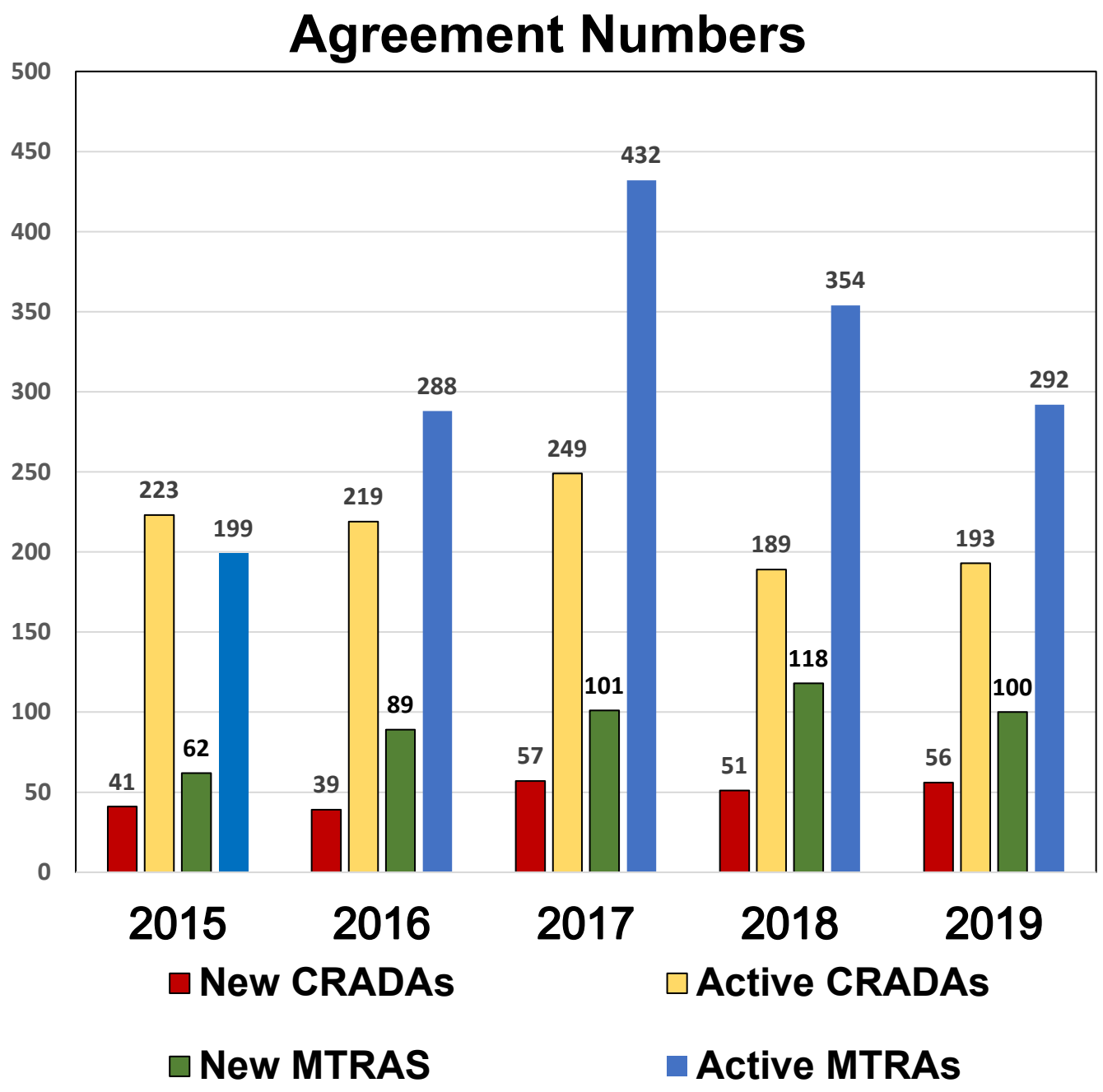


Figure 2. Number of collaborative research agreements (CRADAs, MTRAs, and other agreements, including Trust Fund Cooperative Agreements, Reimbursable Agreements, Interagency Agreements, and Non-Funded Cooperative Agreements) executed by type in FY 2019

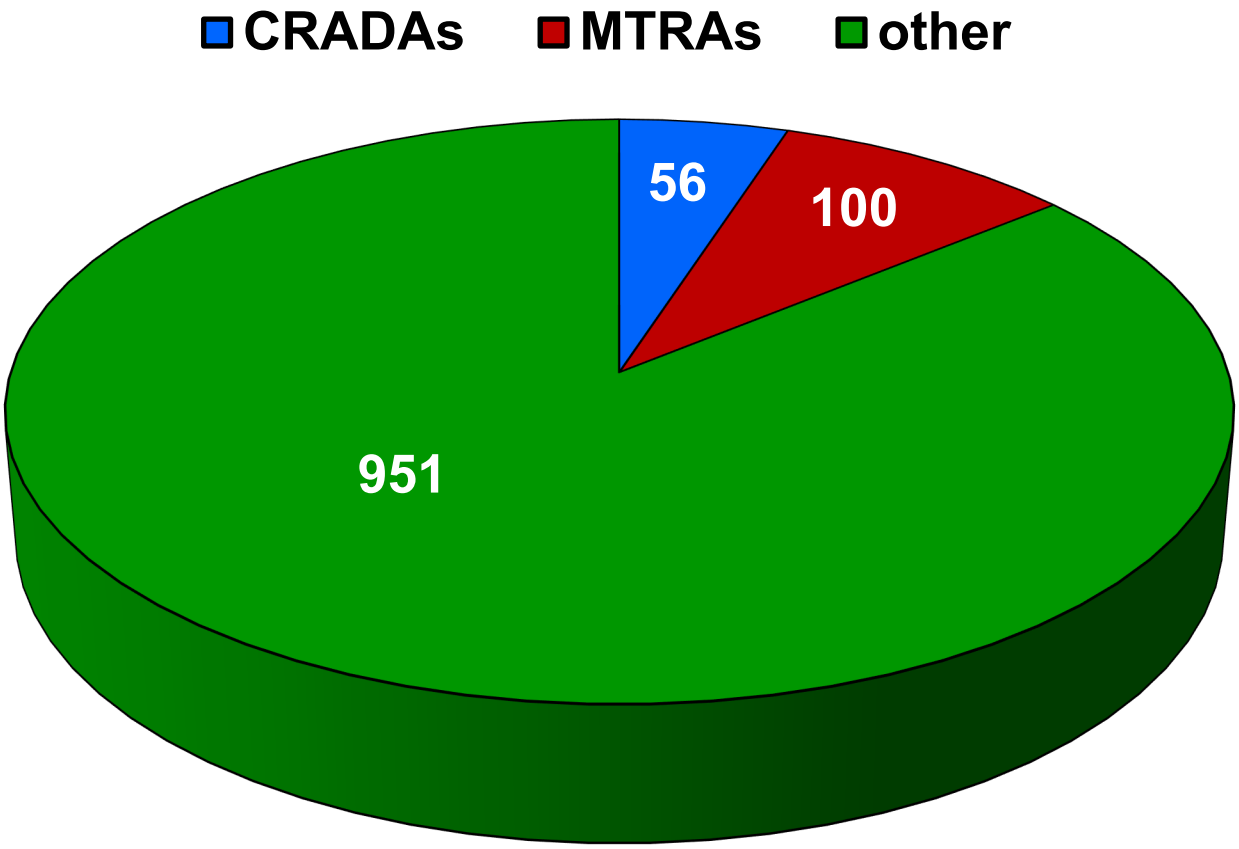


Figure 3. Number of invention disclosures, patent applications filed, and patents issued. The year in which a patent issues is not the year in which the patent is filed. The increase in the number of invention disclosures in FY 2018 was the result of a significant increase in biological materials disclosures.

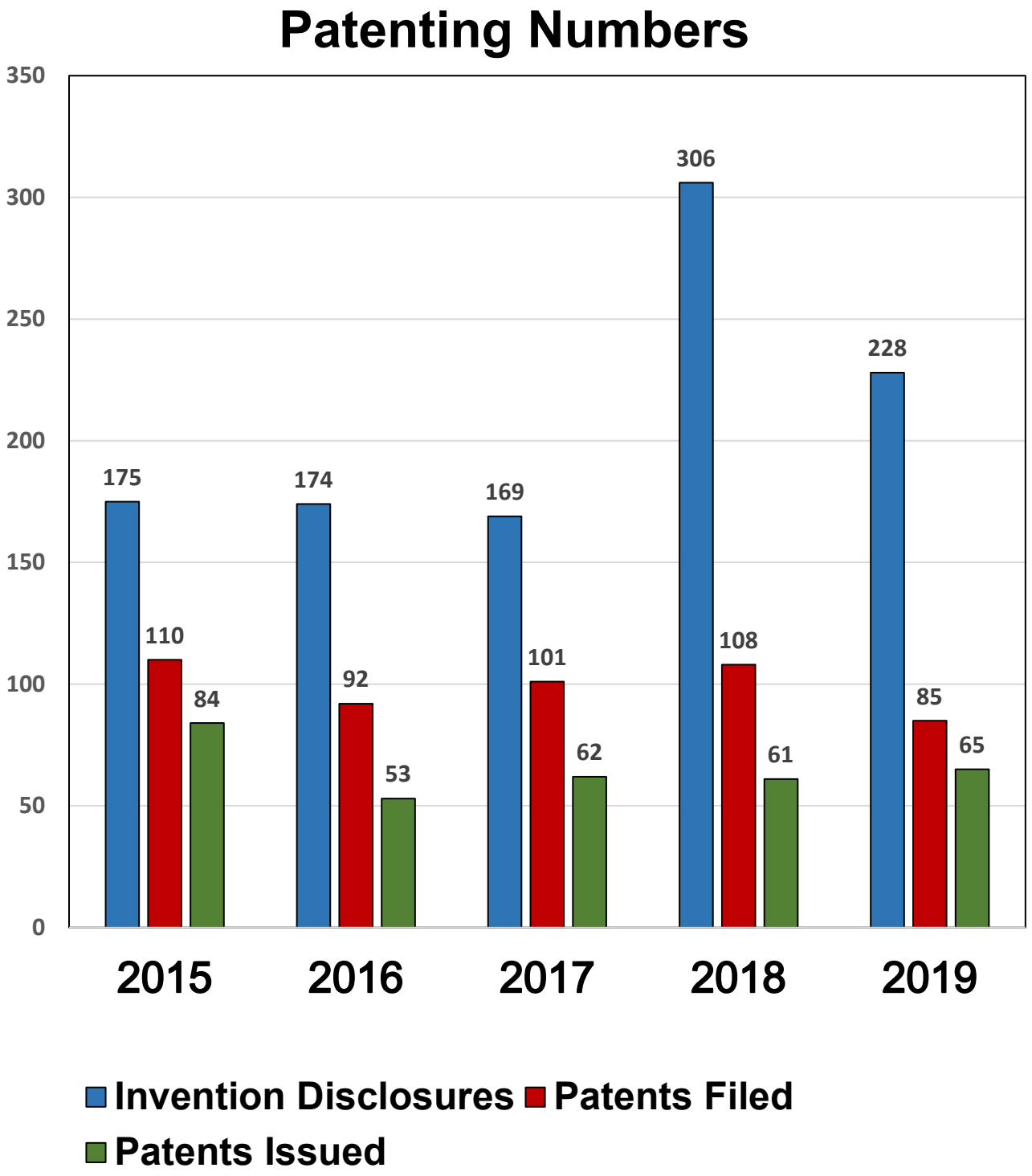


Figure 4. Percentage of patents issued in FY 2019 by scientific discipline

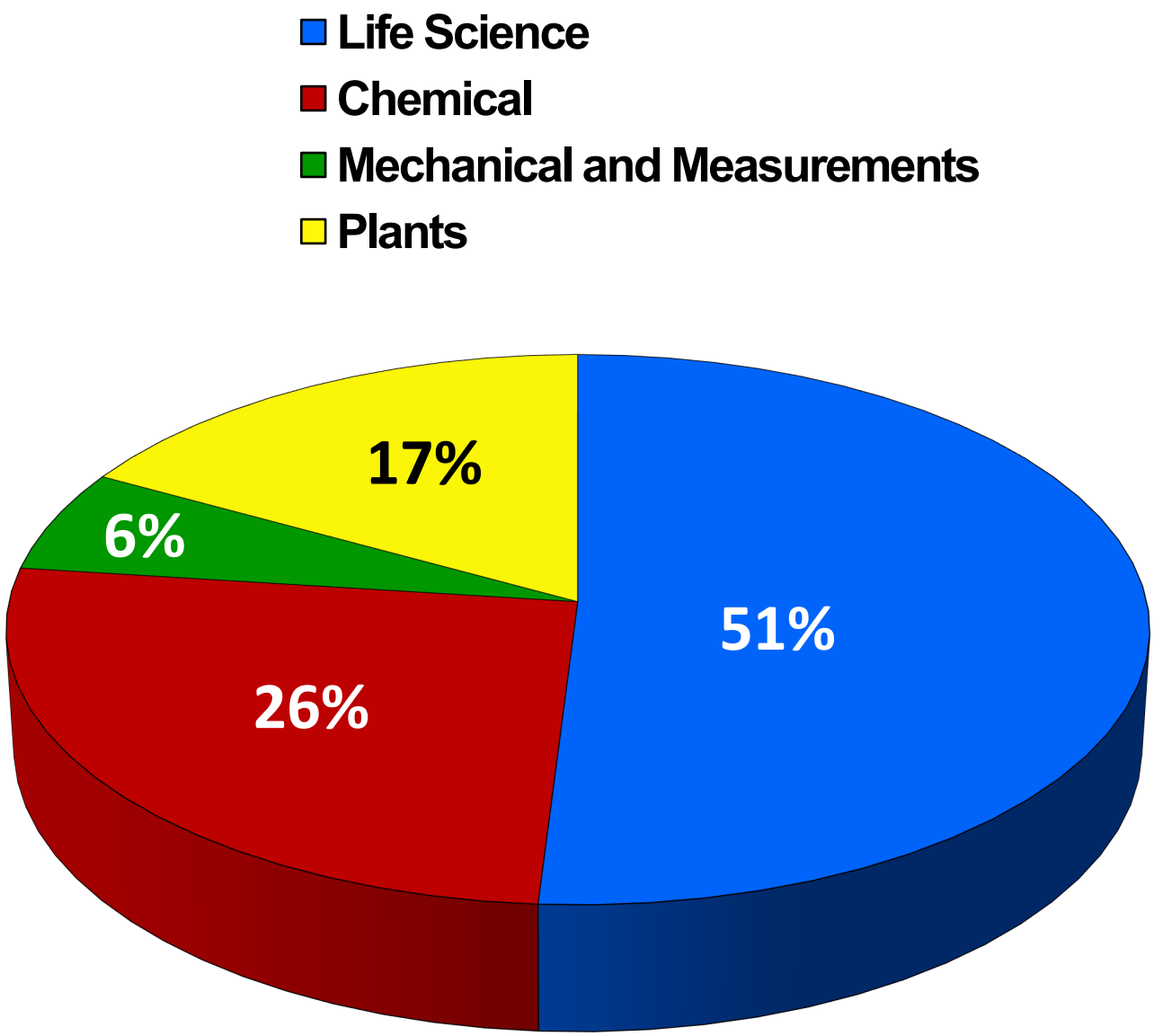


Figure 5. The ratio of patents issued over patent applications filed per year. Although the year in which a patent is issued is not typically the year in which the patent application is filed, over time the ratio of patents issued over the number of patent applications filed is an indicator of "judicious" patenting. Over the last 4 years, this indicator suggests that ~65 percent of the patent applications result in an issued patent.

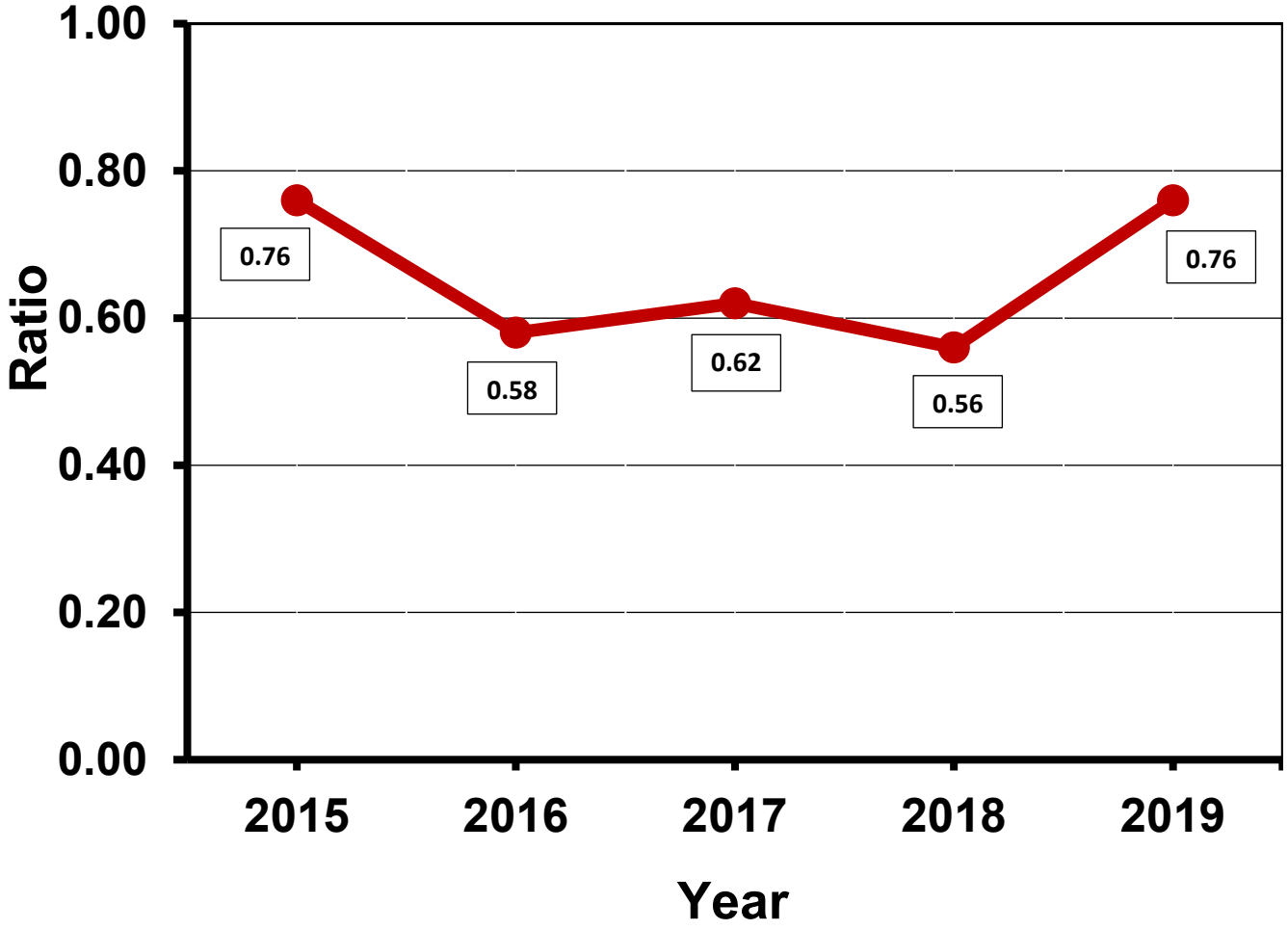


Figure 6. Number of license types per year

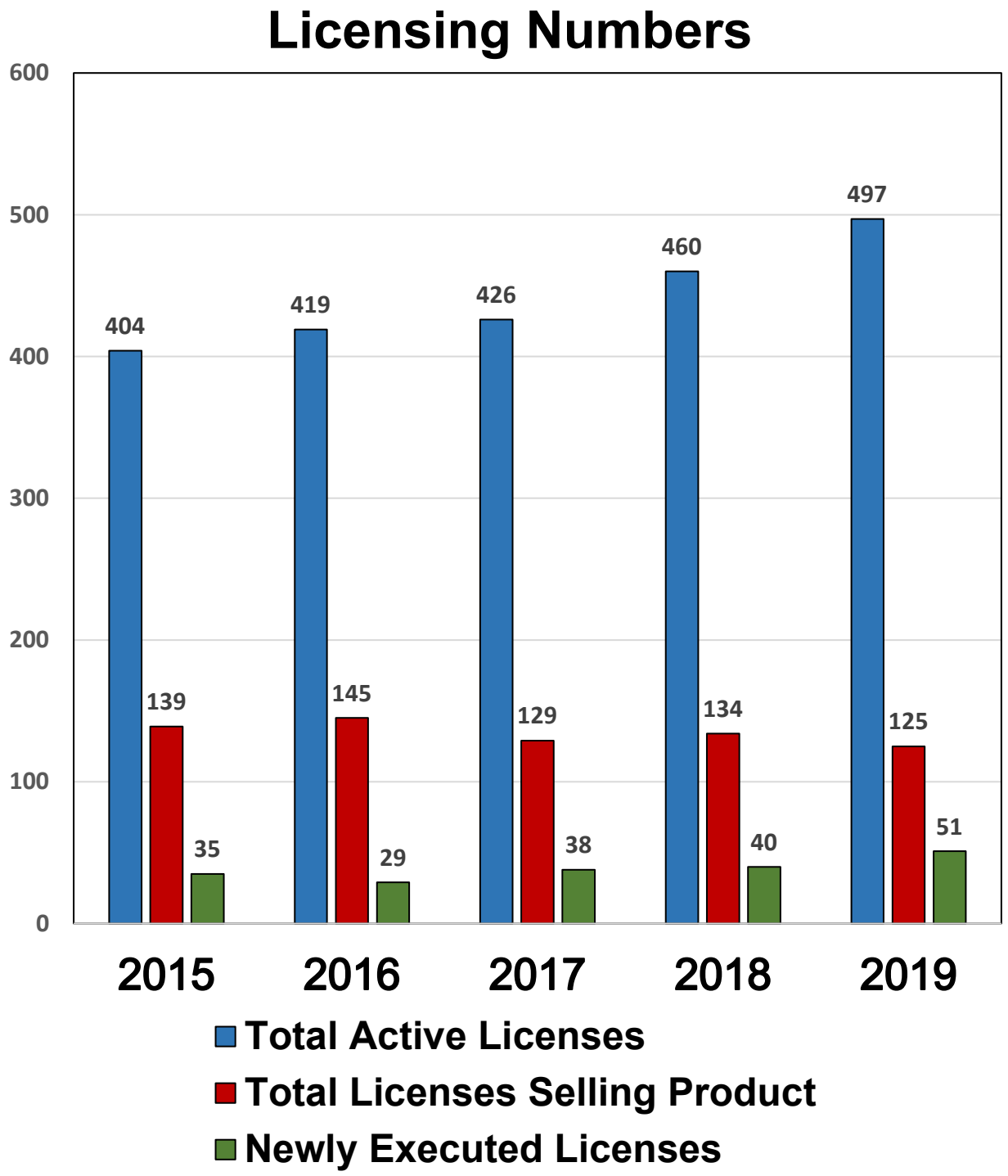


Figure 7. Earned license royalty income (ERI) over time. The lower income in FY 2018 was due to two of the top revenue generating licenses expiring in FY 2017

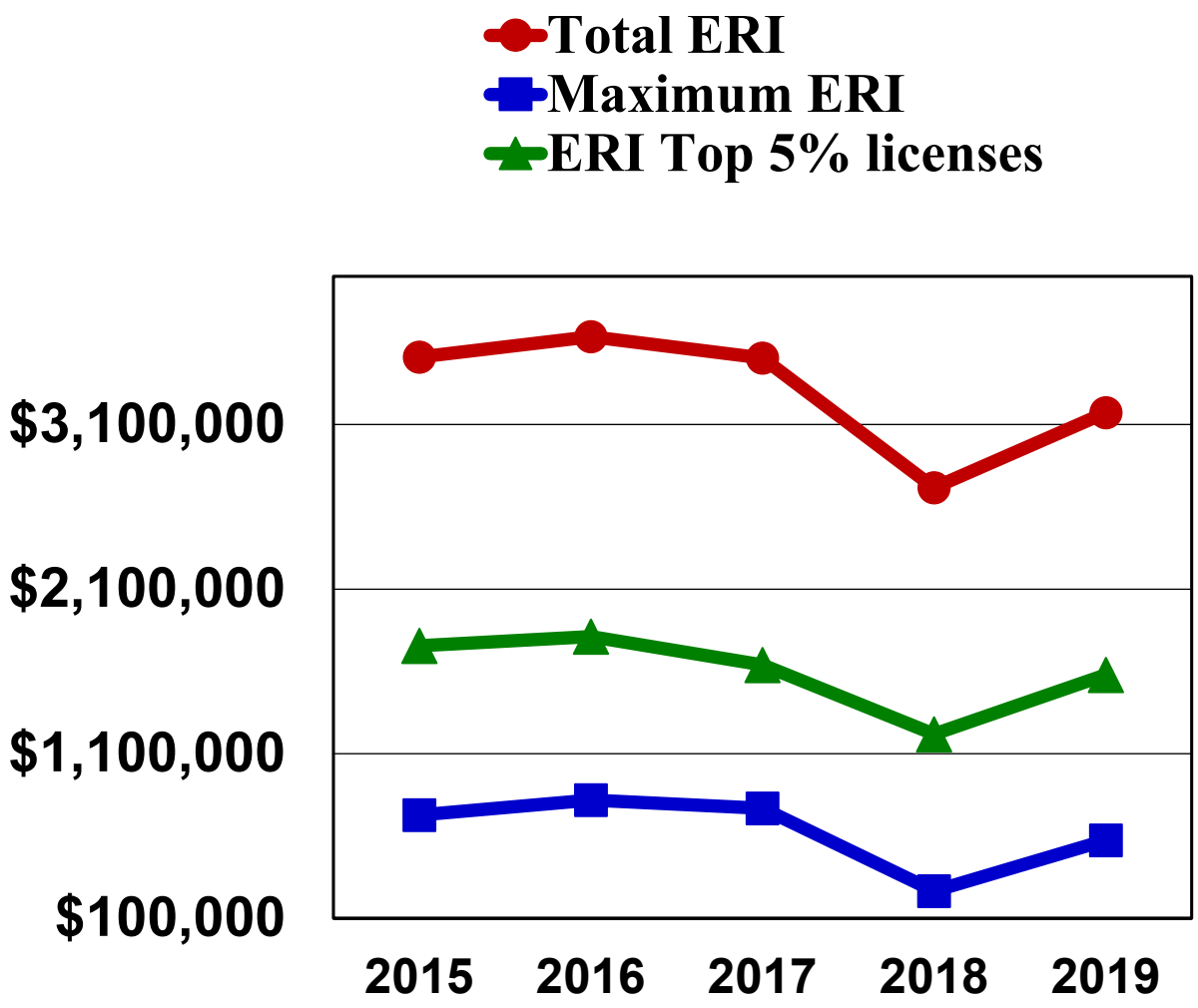


Figure 8. The number of new licenses executed in FY 2019 by business type.

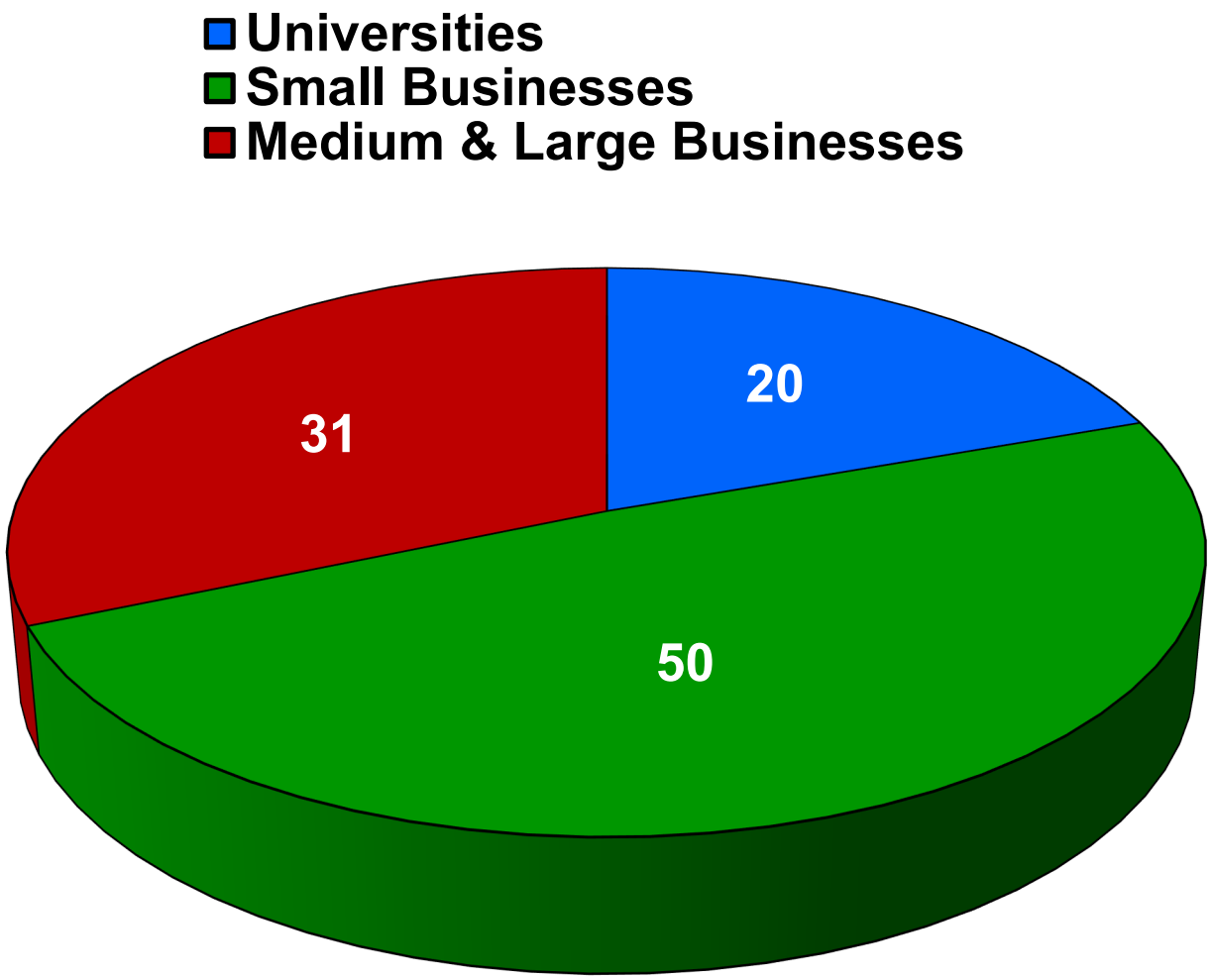


Figure 9. The ratio of newly signed invention licenses over newly issued patents per year. Although the year in which a license is signed is not typically the year in which the patent has issued, over time the ratio of newly signed licenses over the number of newly issued patents is an indicator of "judicious" patenting contemplating among other things commercial viability of the technology. Over the last 4 years, this indicator suggests that ~40 percent of the issued patents are licensed.

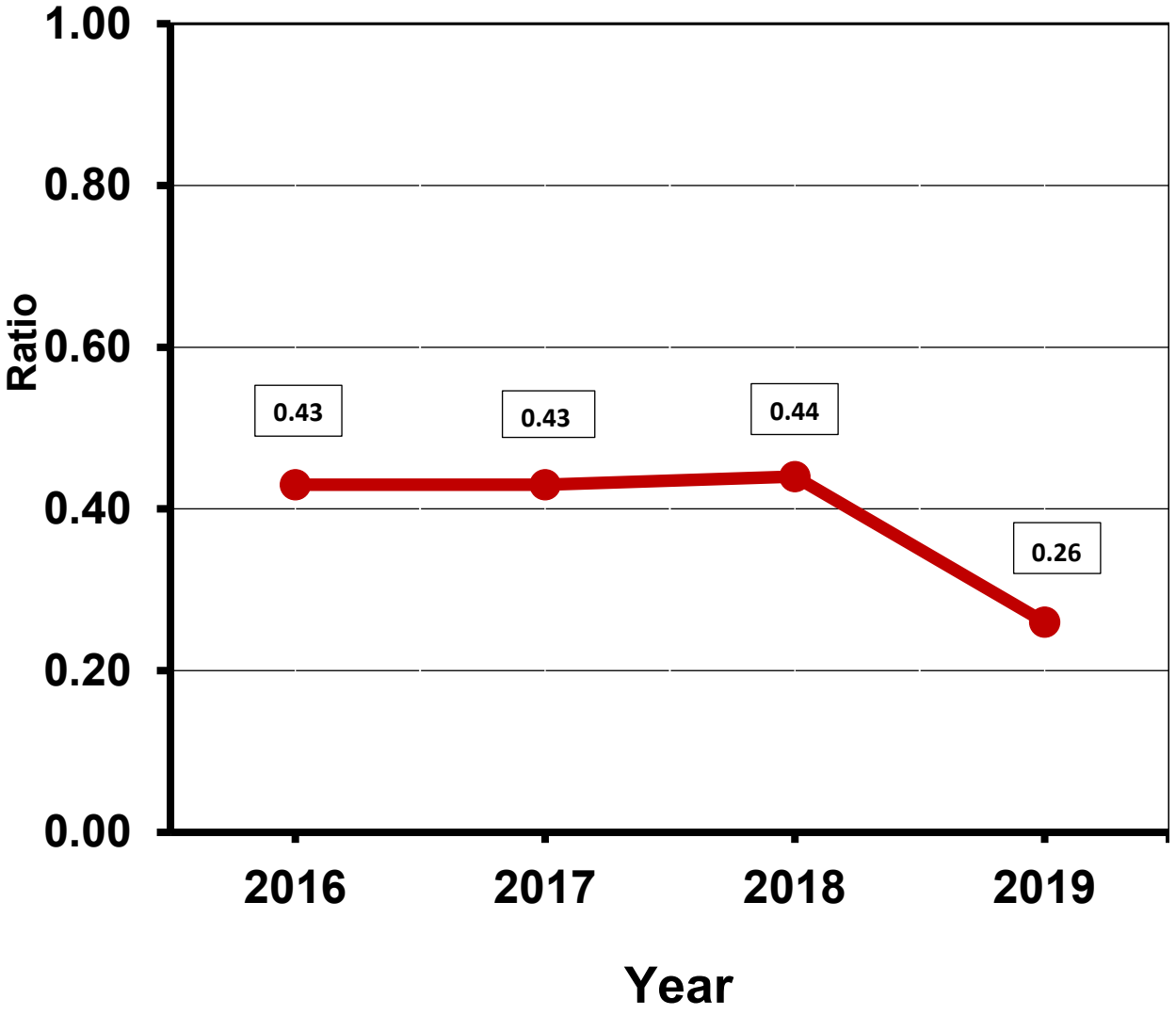
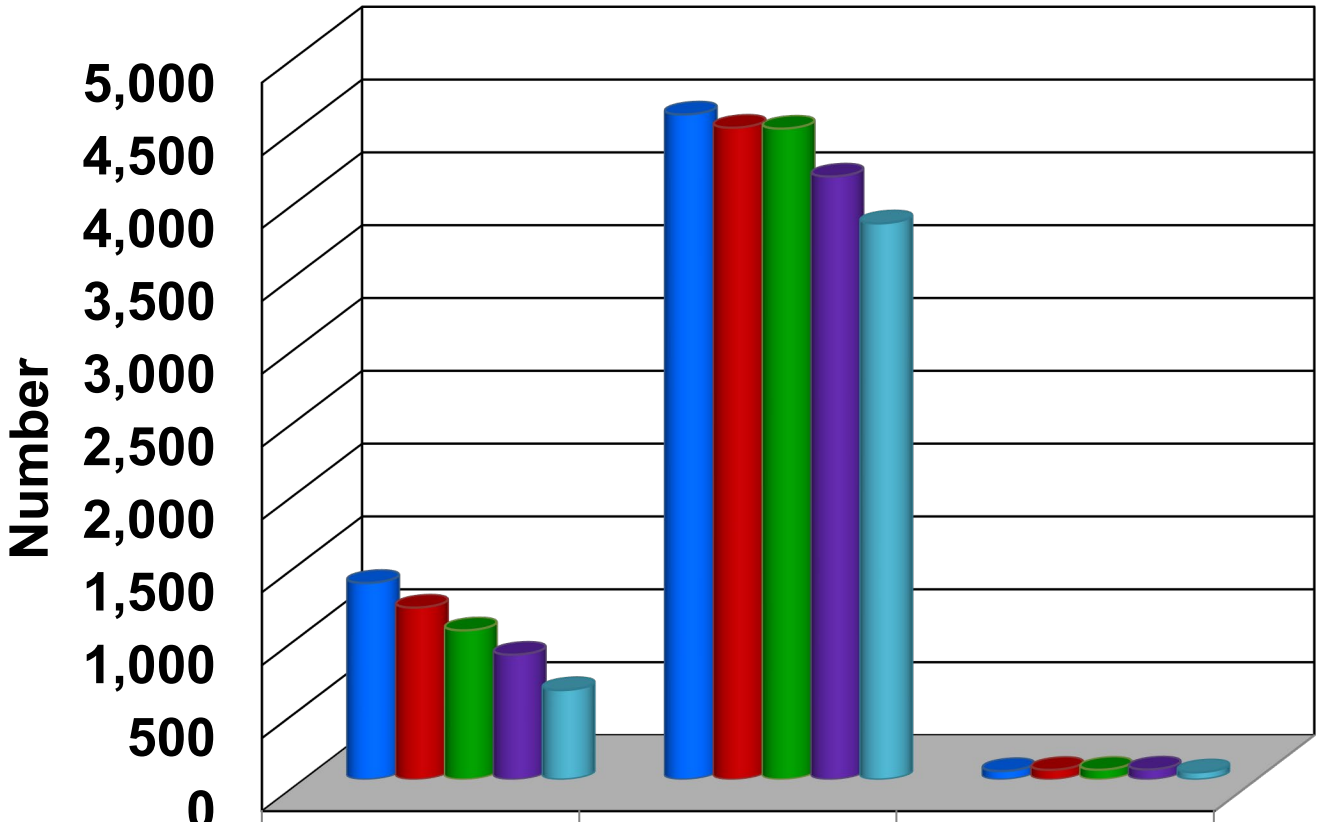


Figure 10. Number of publications per year



	Meeting Abstract	Scientific Journal	Trade Journal
2015	1,347	4,564	57
2016	1,178	4,473	65
2017	1,022	4,467	66
2018	855	4,138	68
2019	612	3,816	48