United States Department of Agriculture
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National Program 305 • Crop Production

FY 2018 Annual Report

The Crop Production National Program (NP 305) supports research to develop knowledge, strategies, systems, and technologies that contribute to greater cropping efficiency, productivity, quality, marketability, and protection of annual, perennial, greenhouse, and nursery crops, while increasing environmental quality and worker safety.

The Nation's rural economic vitality depends on the ability of growers to profitably produce and market agricultural products including food, fiber, flowers, industrial products, feed, and fuels, while enhancing the natural resource base of crop production. Future financial success depends on increasing productivity, accessing new markets for specialized products, developing technologies to provide new opportunities for U.S. farmers, and utilizing tools and information to mitigate risks and enable rapid adjustments to changing market conditions. The farm sector has great and varied needs driven by a wide variety of resource, climatic, economic, and social factors that require an equally diverse array of solutions.

Contemporary cropping enterprises are complex and depend on highly integrated management components that address crop production and protection, resource management, mechanization, and automation. U.S. annual, perennial, and greenhouse (protected systems) crop production are based on the successful integration of these components. The development of successful new production systems requires a focus on new and traditional crops; the availability and implementation of improved models and decision aids; cropping systems that are profitable and productive; production methods fostering conservation of natural resources; efficient and effective integrated control strategies for multiple pests; improved methods, principles, and systems for irrigation; improved mechanization; and reduced inputs – all while sustaining or increasing yield and quality.

Production systems must better address the needs of small, intermediate, and large farming enterprises including those using field-, greenhouse-, orchard-, and vineyard-based production platforms with conventional, organic, or controlled environment strategies. Additionally, adaptation and development of technologies are required to ensure a sustainable and profitable environment for production agriculture. New technologies must address the need for lower cost, higher efficiency inputs that foster conservation of energy and natural resources, while maintaining profitability and promoting environmental sustainability.

In addition, declining bee populations and honey production require special attention. Over the past several years, a myriad of pests and potentially adverse cultural and pest management practices have been threatening many of the bee species required for pollination of multitudinous crops. Colony Collapse Disorder had increased honey bee (*Apis*) over-wintering mortality to over 30 percent; and while CCD incidence has declined, bee mortality remains unsustainably high. Also, as new crops or niches are introduced, there is an increasing need for non-honey bee pollinators for specific crops or protected environments.

National Program 305 coordinates and collaborates extensively with other ARS National Programs, universities, and industries in adapting and incorporating technologies, approaches, and strategies that

enable the advancement of the Nation's agricultural industry and enhanced international competitiveness.

This National Program is divided into two main research components:

- **Component 1: Integrated Sustainable Crop Production Systems**
- **Component 2: Bees and Pollination**

Below are National Program 305 accomplishments from fiscal year 2018, grouped by research component. This report is not intended to be a progress report describing all ongoing research, but rather an overview that highlights accomplishments, some of which are based on multiple years of research (not all research projects will reach an "accomplishment" endpoint each year).

ARS welcomes your input regarding our ongoing research programs. If you have any questions, please do not hesitate to contact the National Program 305 team: Kevin Hackett (Kevin.Hackett@ars.usda.gov), Joe Munyaneza (Joseph.Munyaneza@ars.usda.gov), Tim Rinehart (tim.rinehart@ars.usda.gov), Jack Okamuro (jack.okamuro@ars.usda.gov), and Roy Scott (roy.scott@ars.usda.gov)

Component 1 – Integrated Sustainable Crop Production Systems

Native pollinators support consistent high sunflower yields. Low or inconsistent yields are challenging for individual sunflower growers and the overall sunflower market. Pollinators are needed to ensure high yields, especially when sunflower hybrids do not effectively self-pollinate because of crop genetics or environmental conditions during flowering. ARS scientists at Fargo, North Dakota, grew 15 confection sunflower hybrids over two years and documented contributions of bee pollination to crop yields. On average, bees accounted for 26 percent of yield and lines that attracted more bees obtained higher benefits from pollinators. Although honey bee colonies were located adjacent to the research plots, almost all bee visits to confection sunflowers were by solitary wild bees. These results document the contribution of wild bees to sunflower yield increases and their clear preference for certain hybrids. Growers are now using bee conservation as part of crop management, and breeders are now using pollinator attraction as a component of inbred and hybrid development.

A non-invasive method to quantify starch reserves at micrometer resolution. Starch is the primary energy storage molecule used by plants to fuel respiration and growth during periods of limited photosynthesis. Until now, starch could only be measured using destructive techniques, which limited studies on carbohydrate metabolism in living plants. Prior methods also lacked adequate spatial resolution to study starch metabolism in different cell types. ARS researchers at Davis, California, Yale University researchers, and scientists at University of California, Davis, used X-ray microcomputed tomography and a novel machine-learning algorithm to quantify plant starch content over time within the woody stems of living grapevines. After validating the machine-learning algorithm, the spatial distribution of starch was characterized in woody stems at micrometer resolution as the plants were exposed to experimental conditions that halted photosynthesis and starch production. This new study tool has applications to many horticultural crops and will support producers who are under increasing pressure to minimize water use without limiting crop longevity or yields.

Brown marmorated stink bug (BMSB) commercial pheromone lure development. BMSB is a highly invasive pest of agricultural and nursery crops and is a nuisance when it invades homes to overwinter. Based on the identification of the BMSB pheromone and pheromone synergist, ARS researchers at Kearneysville, West Virginia, and university collaborators around the country developed lures that are now commercially available from three commercial companies, AgBio, Trece and AlphaScents. The lures can be used with crop-compatible trap designs to measure BMSB presence, relative abundance, and seasonal activity.

Hot water and steam can be used to sanitize plastic nursery pots and trays for weed seed. Seeds of many weeds, particularly bittercress and creeping wood sorrel, stick to plastic nursery containers and trays and are reintroduced into production systems when that plastic is reused. ARS scientists in Wooster, Ohio, determined the specific temperatures and exposure times necessary when using either hot water or steam to kill weed seeds on plastic containers and propagation trays. Temperatures of 194^{o} F provided nearly complete control of seeds for both species. The results of this work can be used by greenhouse and nursery producers to control weed seeds between crops and drastically reduce weed populations in propagation and other phases of production where herbicides are limited.

Vulnerability of field crops to temperature changes in the southwestern U.S. ARS researchers at Davis, California, and Las Cruces, New Mexico, collaborated with researchers at Lawrence Berkeley National Laboratories and the University of Idaho to assess the sensitivity, exposure, and vulnerability of eight field crops to increased temperatures at midcentury (2040-2069). This county-level spatial simulation revealed the complexity of temperature increases and provides guidance for prioritizing agricultural transformations and adaptations to help minimize land-use conflicts. Future temperature shifts were associated with changes in the composition and quantities of wheat, barley, oats, alfalfa, maize, cotton, rice, and safflower crops. For example, heat stress is projected to reduce maize yields by 27 percent, representing a 12 percent decline on top of known historic yield losses due to heat stress, and may reduce cotton yields by 38 percent, the latter of which will be greatest in the southern Central Valley, eastern New Mexico, and southern Arizona. The area suitable for cotton may double and expand northward, 14 percent of the current land used for alfalfa production will become be unsuitable, and 20 percent of current land used for maize production will be lost. However, in some cases, simply moving field crops to new areas puts them where high-value specialty crops are already grown. Land management goals must reflect an appropriate balance between agriculture, conservation, and other land uses as resources become affected by climate changes, particularly in the southwest U.S. region.

Rootstocks identified for sapodilla production in Puerto Rico. An increasingly global economy has generated a greater demand for healthy and more diverse food products and has opened a window of opportunity for commercial tropical fruit production and marketing. Sapodilla is a delicious tropical fruit, but trees grow slowly, so growers need long-term research to ensure profitable production. ARS scientists in Puerto Rico conducted a 7-year field study to determine the yield, fruit quality, nutrient composition, and scion/rootstock compatibility of the cultivar ‘Prolific’ that was grafted onto 16 rootstocks at the USDA-ARS Research Farm in Isabela, Puerto Rico. Fruit from the most productive rootstocks averaged 4,479 fruit/ha, or 1,245 kg/ha. The average individual weight of fruit was 282 grams and ranged from 264 grams to 303 grams. This study provides the first information from a replicated experiment on fruit quality traits, leaf nutrient composition, and scion/rootstock compatibility of sapodilla cultivar ‘Prolific’ tropical fruit growers.

New catch plate design for mechanical blueberry harvesters. Blueberry growers want to replace expensive hand pickers with machines to harvest blueberries, but current blueberry harvesting machines use hard fruit catching plates that cause significant impact damage to the harvested blueberries falling on them. To machine harvest blueberries without bruise damage, ARS researchers at Kearneysville, West Virginia, developed durable catch plates (U.S. Patent No. 9750188) and field test results showed that the machine with new catch plates harvested blueberries with significantly less bruise damage. In 2018, two commercial blueberry harvesting machines with the new catch plate design were built.

Integrating aerial imaging and variable rate technology for precision herbicide application. Remote sensing and variable rate technology are becoming more available for aerial applicators, and practical methodologies for effectively integrating these technologies are needed for site-specific aerial applications of crop production and protection materials. ARS scientists at College Station, Texas, demonstrated how to integrate an airborne imaging system and a variable rate aerial application system for site-specific management of the winter weed henbit. Results showed that the imaging system was effective for mapping henbit infestations and that the variable rate system could accurately deliver the product at the desired rate to the prescribed areas for effective weed control. The methodology and results from this study will be useful for aerial applicators to incorporate airborne imaging and variable rate application systems into their aerial application business to increase their capabilities and profits.

Mapping pigweed with free data and open source software. Pigweed has become a troublesome weed in southeastern U.S. agricultural systems, and agriculturalists need information on areas affected by pigweed to implement effective management control strategies. ARS scientists at Stoneville, Mississippi, used free and open-source geographic information system (GIS) software (QGIS), free government data, and online plant databases to develop and publish a county-scale geographic information database showing the distribution of three pigweeds: Palmer amaranth, redroot pigweed, and water hemp. Database queries were used to demonstrate applications of GIS for precision agriculture applications at the county level, such as tallying the number of counties affected by the pigweeds, identifying counties reporting glyphosate-resistant pigweed, and identifying cultivated areas in counties with glyphosate-resistant pigweeds. This research demonstrated that free and open-source geographic information software such as QGIS has strong potential as a decision support tool and could be used for developing precision weed management at the county scale.

Component 2 – Bees and Pollination

Successful cryopreservation of a honey bee embryo. ARS scientists from Fargo, North Dakota, collaborated with ARS bee breeders at Baton Rouge, Louisiana, to create the world's first cryopreserved honey bee embryo. Honey bee sperm is currently stored by the ARS National Animal Germplasm Program in Fort Collins, Colorado, and sperm preservation provides biodiversity, but embryo preservation enables breeders to access genetically identical lines of bees. This is a major advancement in the ability to improve the biosecurity of honey bee germplasm and the accessibility of the nascent National Honey Bee Germplasm Repository.

Seasonal pollen nutrients align with seasonal bee activity. ARS researchers in Tucson, Arizona, found that spring pollens provided higher concentrations of necessary proteins and fatty acid nutrients than fall pollens. The spring nutrients support brood rearing, foraging, and reducing the incidence of brood diseases, while fall pollens contained more nutrients that mobilize stored resources needed to

thermoregulate the winter cluster. The source of pollen even affected changes in adult bees, which grew larger brood food glands when fed spring pollen than when fed fall pollen. Findings from this study underscore the need for flowering plants to be available to bees from spring through fall, and that seasonal nutritional needs must be considered when formulating pollen supplements for bee colonies.

Antibiotic treatment could increase honey bee vulnerability to fungal disease. Antibiotics indiscriminately wipe out both good and bad bacteria, leading to antibiotic resistance and causing other potential bee health problems. ARS scientists in Beltsville, Maryland, discovered that disruption of honey bee gut bacteria by antibiotic treatment could interfere with bee immunity and make bees more susceptible to Nosema, a fungal disease. This study adds new evidence that antibiotic treatment not only leads to the complex problem of antibiotic resistance, but also damages gut microbial communities that help regulate immune function in honey bees.