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National Program 305 • Crop Production

FY 2021 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 indoor farm, 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 controlled environment crop production (e.g., greenhouse and other protected systems) 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 and diseases; improved methods, principles, and systems for irrigation; improved mechanization and automation; 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-, indoor farm-, 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 2021, 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@usda.gov), Joe Munyaneza (joseph.munyaneza@usda.gov), Tim Rinehart (tim.rinehart@usda.gov), Jack Okamuro (jack.okamuro@usda.gov), and Roy Scott (roy.scott@usda.gov)

Component 1 – Integrated Sustainable Crop Production Systems

Winter oilseed cover crops suppress early-season weeds. ARS researchers and university partners in Morris, Minnesota, are developing Midwest U.S. crop production systems that use winter camelina and pennycress as an oilseed cash cover crop that can also suppress the growth of weeds. They found pennycress, as an overwintering crop, reduced spring and early summer weed growth from 97 to 100 percent, while winter camelina suppressed weeds from 85 to 87 percent. When used as cash cover crops, these oilseeds can reduce herbicide use and help control herbicide resistant weeds. These findings have been shared via a refereed publication and will greatly benefit farmers, agronomists, extension educators, and others interested in adopting this new cropping practice. (NP305, C1, PS1A, Project No. 5060-21220-007-00D)

A new and rugged ground-based method estimates crop water use. Farmers in the drought-stricken western United States require better tools to improve precision irrigation management. Reliable ground-based sensors can complement efforts to quantify crop water use and measure crop stress remotely with satellites and drones. ARS researchers in Davis, California, along with University of California-Davis collaborators, found a way to utilize rugged infrared temperature sensors to measure crop water use and stress down to the single plant level. This new method determines crop water use by measuring changes in crop temperatures every second. The effectiveness of this new method was shown in vineyards and tree crop orchards by comparing measurements against gold standard methods. This breakthrough enables the use of these durable, readily available sensors to improve precision irrigation management and environmental stewardship. (NP305, C1, PS1B, Project No. 2032-21220-008-00D)

Upgrades to an intelligent spray system for specialty crops. A commercially upgraded version of the intelligent spray system was developed by ARS scientists in Wooster, Ohio, in collaboration with Smart Guided Systems LLC. New features in the system includes tree counting, tree size, foliage density heat map comparison capability, liquid volume sprayed per plant, maps of sprayed plant locations, cloud sync feature, and other options. The upgraded commercial system has been used as a retrofit kit on existing sprayers by U.S. growers and other countries for crops including citrus, nursery, pecan, blueberry, peach, almond, apple, pear, and grape. Pesticide usage reduction ranges from 30 to 85 percent, depending on crop types and growth stages. The John Deere Company now sells the commercial intelligent spray control system mounted on tractors for high value crop applications. This environmentally sustainable product received the 2021 SIMA Gold Metal, which is the largest agricultural innovation award in Europe. In addition, the Permanent Crop Analyzer, a part of the commercial intelligent spray system, was awarded the 2021 Top-10 New Product winners by the World Ag Expo. (NP305, C1, PS 1B 1C 1D 1E; C2, PS 2B; Project No. 5082-21620-001-00D)

Elevated carbon dioxide and chronic high temperature or drought stress reduce nitrogen uptake in crop plants. Climate change is predicted to result in conditions that are warmer and drier, and that contain higher concentrations of carbon dioxide (CO_2). ARS scientists in Toledo, Ohio and researchers from the University of Toledo found that plant stress induced by elevated CO_2 levels and chronic high temperatures negatively impacts tomato growth, nitrogen (N) uptake rates, and N transport from the roots to the shoots. They also demonstrated that elevated CO_2 levels and chronic high temperatures negatively impact N concentrations and reduce the protein content of wheat. Furthermore, researchers showed that, when coupled with drought-related stress, elevated CO_2 levels result in the reduction of plant phosphorous (P) levels, even though an increase in nutrient uptake transporters in the roots is meant to counteract such stresses. Collectively, these studies indicate that plant growth, yield, and quality will be negatively affected by predicted climate scenarios. These research findings will help plant breeders focus on developing improved and resilient cultivars that are well-suited for potential climate change conditions. (NP305, C1, PS 1D, Project No. 5082-21000-001-00D)

Weed identification in cropping systems using advanced technology. Since the dawn of plant taxonomy, manual methods have been used to identify plants, but in today’s world, few want to spend the time necessary for correct identification. Many weed species can now be identified using sensors and computer programs. ARS researchers in Stoneville, Mississippi, used remote sensing focused on the narrow band related to biophysical and biochemical properties to determine different species of *Amaranth*, a problem weed species in many crops. The biochemical index and red edge index were the most consistent in *Amaranth* spp. differentiation. Using this approach could help in identifying herbicide resistant weeds, which would be a tremendous advantage for growers. (NP305, C1, PS1E, Project No. 6066-22000-081-00D)

Rethinking mulch use in blueberry production. Many growers are using woven polypropylene ground cover, which is often referred to as weed mat, in commercial blueberry fields. Weed mat is cost effective for weed control, but, unlike the previous industry standard of using sawdust mulch, it reduces soil health and fruit production within a few years. An ARS researcher in Corvallis, Oregon, and Oregon State University collaborators evaluated the potential of using a dual system in which sawdust is placed underneath the weed mat. The dual system helped plant establishment and increased yield by as much as 20 percent in the second growing season. Furthermore, weed mat protected the sawdust layer from erosion by wind and rain and was more effective for weed control than sawdust alone. Although there is an extra upfront cost to the dual system, net returns are higher once factors such as labor, maintenance, and fruit sales are considered. (NP305, C1, PS1B, Project No. 2072-21000-055-00D)

Winter annual cover crops scavenge excess soil nitrate nitrogen. The leaching and runoff of excess soil nitrate nitrogen (N) from corn-soybean cropping systems in the upper Midwest is a major issue because the N that is lost pollutes ground and surface waters. ARS researchers in Morris, Minnesota, collaborated with university researchers from Minnesota, Iowa, and North Dakota and showed that winter camelina, pennycress, and winter rye cover crops inter-seeded into standing corn and soybean crops in the fall are effective at scavenging excess soil N left behind by corn and soybean. Three out of four field sites showed a significant decline in soil N—up to 76 percent—due to cover crop uptake and sequestration, compared to a traditional winter fallow corn-soybean or soybean-soybean rotations. Most of the scavenging by the cover crops occurred in spring when soils are most susceptible to N leaching and runoff. These published findings will significantly benefit farmers, agronomists, extension educators, and others working to incorporate cover crops into corn and soybean rotations. (NP305, C1, PS1A, Project No. 5060-21220-007-00D)

Supporting agricultural chemical applicators with new online tools. Drift from chemical applications can damage crops, animals, people, or other living organisms. Determining unfavorable conditions for spraying can be challenging, especially during temperature inversions. ARS researchers in Stoneville, Mississippi, developed a real-time online guide for determining the proper time to schedule aerial chemical applications. The web application has been adapted for use on mobile devices, such as smartphones and tablets, and provides timely guidance for aerial chemical applicators and producers in avoiding drift and subsequent air quality issues. (NP305, C1, PS1E, Project No. 6066-22000-081-00D)

Ambrosia beetle attacks following short-term flooding are less damaging than previously thought. Invasive ambrosia beetles are pests of tree crops, such as apples and ornamental trees; they bore into trees and create galleries in which they raise their offspring. Currently, nursery growers tend to cull trees with any sign of ambrosia beetle attacks. ARS researchers in Wooster, Ohio, discovered that ambrosia beetles were unsuccessful in colonizing trees during short-term flooding events. Trees usually survived the short-term flooding and unsuccessful colonization attempts. These results indicate growers can retain trees attacked during short-term flood events instead of prematurely culling them. (NP305, C1, PS 1D; Project No. 5082-21000-001-00D)

Desiccating corn improves winter camelina establishment. Planting winter camelina as a cover crop after corn is challenging because corn is often harvested in late fall, allowing little time to establish cover crops before the soil freezes. ARS researchers in Morris, Minnesota, and a university partner demonstrated that chemical desiccation of corn at its mid-development stage allowed corn to be harvested earlier and provided an additional period of 1 to 3 weeks to plant camelina. This led to better camelina establishment and improved seed yield, compared to previous studies of inter-seeding camelina into standing corn prior to its harvest. Furthermore, desiccating corn at mid-development did not reduce grain yield or test weight. These published results will benefit farmers, researchers, agronomists, extension educators, and crop consultants looking for ways to improve cover crop establishment in corn-soybean cropping systems. (NP305, C1, PS1A, Project No. 5060-21220-007-00D)

Effective management strategies for *Cytospora* dieback developed for Washington wine grapes. Grape growers in Washington now have management tools for grapevine trunk diseases, including *Cytospora* dieback. ARS researchers in Davis, California, tested two fungicides in eastern Washington against fungal species and isolates, which greenhouse studies had shown the to be virulent pathogens, from Washington vineyards. Based on consistently lower detection rates of *Cytospora*-dieback pathogen *Cytospora viticola*, and the *Esca* pathogen *Phaeomoniella chlamydospore,* one application of thiophanate-methyl after pruning was the most effective treatment. In 2021, thiophanate-methyl was labeled for dormant-season applications against trunk diseases in Washington wine grapes. A survey of Washington vineyards indicates that *Cytospora viticola* appears to be a common pathogen, so availability of thiophanate-methyl gives Washington growers the opportunity to adopt preventative practices against trunk diseases in young, healthy vineyards and after pruning in mature vineyards. (NP305, C1, PS1B, Project No. 2032-21220-008-00D)

Winter camelina seed oil for food or fuel depends on where it is grown. Saturated vegetable oils are more suitable for making biofuels, whereas unsaturated oils, which are high in omega-3 and omega-6 fatty acids, are favored for food uses. Camelina is a new oilseed being developed in North America and Europe for food and bioenergy. ARS researchers in Morris, Minnesota, designed a study and collaborated with scientists in North America and Europe to determine how the growth environment, such as soil and climate, affected winter camelina seed oil content and quality. Overall, hot and dry growth environments led to greater saturation of camelina seed oil, which may be better suited for making biofuels. Environments with cooler temperatures, longer growing seasons, and evenly distributed precipitation favored production of unsaturated oil, which is better suited for healthy food uses. Theses published results will benefit growers and specialty oil industries searching for the best regions to produce or purchase camelina for food and/or fuel uses. This information also provides crop breeders and other researchers with a better understanding of how environment affects oilseed quality. (NP305, C1, PS1A, Project No. 5060-21220-007-00D)

Characterization of fungal and bacterial microbiomes in grape must demonstrates unique identity based on vineyard location. Microbiomes in Pinot noir grape must, which is the juice resulting from the freshly crushed fruit, reflect their place of origin. ARS researchers in Davis, California, and University of California, Davis, collaborators measured Pinot noir grape must microbiomes for two production seasons in Oregon and California and demonstrated that the microbiomes have unique identities that reflect growing region and climate. Different levels of specific microbial groups varied with vintage, growing season precipitation, and fruit maturity metrics. Bacterial microbiomes were most strongly influenced by precipitation and their dispersal was not limited by distances between vineyard or region. In contrast, fungal microbiomes were structured by precipitation and growing degree days, and experienced dispersal limitation, indicating that the local vineyard itself was a source for abundant fungal taxa. Long-term outcomes from this work include the identification of vineyard management practices and abiotic conditions that can be adjusted to manipulate the fungal and bacterial microbiomes to elicit desired grape production results. (NP305, C1, PS1B, Project No. 2032-21220-008-00D)

New tissue nutrient test shows promise in grapevines. Grape growers use leaf blades, or petioles, collected during the growing season to diagnose vine nutritional status, but an earlier indicator of vine nutrient status would give growers enough time to develop more efficient nutrient management plans for the year. An ARS researcher in Corvallis, Oregon, collected dormant-season (winter) pruning wood for 4 years to see if it could be used to predict vine nutrient status in the subsequent growing season. Winter pruning wood was an excellent predictor of vine phosphorus levels and a good predictor of potassium levels during the next growing season, but the winter samples were not effective in predicting vine nitrogen status. These promising results will be further tested as part of a nationwide study to find new tools for grape producers to better monitor nutrition. (NP305, C1, PS1B, Project No. 2072-21000-055-00D)

Several Phytophthora species cause rhododendron root rot. Rhododendrons are an important component of the ornamental nursery industry but are prone to *Phytophthora* root rot. One *Phytophthora* species, *P. cinnamomi*, was previously thought to be the primary pathogen causing rhododendron root rot. Recent research suggests there are several other *Phytophthora* species that may cause root rot, but little was known of their virulence and risk to the industry. ARS researchers in Corvallis, Oregon, and researchers at Oregon State University determined that at least three other *Phytophthora* species isolated from Oregon nursery plants can cause similar disease severity as *P. cinnamomic* but found that not all species are equally virulent. This research provides valuable information for other researchers and industry in developing more effective disease control measures. (NP305, C1, PS1C, Project No. 2072-21000-055-00D)

Transport of nitrate from roots to shoots drives the growth promoting ability of grapevine rootstocks. Grapevine rootstocks are used in viticulture to control pests and vine growth or size, which is related to their ability to acquire nitrogen from soil and to transport it to the shoot. An ARS researcher in Corvallis, Oregon, and Oregon State University colleagues conducted a series of studies in grafted Pinot noir grapevines to investigate nitrogen uptake and transport properties of two rootstocks that are known to differ in how well they promote scion growth. The results showed that the rootstock known to impart greater scion growth transported more nitrate to leaves via greater water movement to individual leaves under both low and high nitrate supply. On the other hand, the less vigorous rootstock had greater root nitrate uptake capacity and allocated more biomass to roots when nitrogen was low. These findings indicate that grapevine rootstocks promote scion growth with greater transport of nitrogen to shoots in the xylem rather than greater uptake kinetics from soil. (NP305, C1, PS1B, Project No. 2072-21000-055-00D)

Lower grape quality due to grapevine red blotch virus. Viruses such as grapevine red blotch virus (GRBV) can have negative impacts on vine productivity and fruit quality. ARS researchers in Parma, Idaho, collaborated with the University of Idaho and industry members on the first report of GRBV in Idaho affecting grape quality on Syrah grapes. Findings from this work indicate GRBV may negatively affect wine quality by lowering grape sugars and pigments. The findings reinforce the importance of obtaining virus-free planting material and monitoring vineyards for GRBV. If the virus becomes widespread, it could eventually pose a threat to the $3 billion grape industry in the United States. (NP305, C1, PS1B, Project No. 2072-21000-057-00D)

A new tool for preventing heat damage in blueberries. Heat damage is a persistent problem in blueberries and results in millions of dollars of fruit loss each year. Growers commonly report sunburn, softening, and discoloration of the berries when temperatures exceed 90 to 95 degrees F. ARS researchers in Corvallis, Oregon, and Oregon State University and Washington State University collaborators determined that sprinkler irrigation was effective at reducing heat damage and developed a model to identify the best time and frequency to operate these systems for cooling. This model is a valuable new tool that will help protect the blueberry industry against costly fruit losses during hot weather. (NP305, C1, PS1B, Project No. 2072-21000-055-00D)

Strategies for dealing with drought in blueberries. Many blueberry growers are facing serious water limitations due to drought and increased demand for water and must often cut back on irrigation during drier years. To identify periods in which irrigation may be less critical for blueberries, ARS researchers in Corvallis, Oregon, and Oregon State University collaborators evaluated the effects of soil water deficits during fruit development in a wide range of blueberry cultivars that ripen at various times between June and September. Water deficits during later stages of fruit development had the largest effects, particularly in cultivars that ripened later, but were less critical during early stages of fruit development, suggesting this may be a good time to reduce irrigation if needed. Results from the study will help blueberry growers increase the irrigation efficiency and reduce losses of yield and fruit quality in years when water is limited. (NP305, C1, PS1B, Project No. 2072-21000-055-00D)

Component 2 – Bees and Pollination

Natural compounds against major viral diseases in honeybees. There are currently no registered treatments or medicines that are effective against honeybee viruses and other microbes. Natural products that range from extracts of secondary compounds in plants and other living organisms to organic molecules provide a rich source of candidates for bee disease treatment. ARS scientists in Beltsville, Maryland, developed efficient and inexpensive screening techniques for testing new natural medicines for bees. Researchers discovered and patented several natural product compounds that are effective hive-based treatments against major bee viruses. These efforts expand the available options to control diseases for beekeepers, helping to ensure better colony health, pollination services and the production of honey and other hive products. (NP305, C2, PS2B, Project No. 8042-21000-291-00D)

New methods to protect managed solitary bees from parasites. Solitary bees, including alfalfa leafcutting and bumble bees, are important pollinators. Alfalfa leafcutting bees are crucial to pollination for seed production, whereas bumble bees are used to pollinate greenhouse crops such as tomato. Alfalfa leafcutting bees need to be incubated prior to adult emergence, but parasitic wasps can destroy the entire population, and, bumble bee species are plagued by parasitic *cuckoo* bumble bees, which steal nest resources. ARS scientists in Logan, Utah, found that adding a dichlorvos insecticide strip at 3 days into incubation of alfalfa leafcutting bees killed several species of parasitic wasps. This treatment was much earlier than previously recommended and did not harm alfalfa leafcutting bees. For bumble bees, a fabricated excluder was designed to prevent *cuckoo* bumble bee invasion and was 100 percent effective at reducing bumble bee colony loss. Using these tools can help ensure effective delivery of alfalfa leafcutting bee and bumble bee pollination services. (NP305, C2, PS2B; Project No. 2080-21000-019-00D)

Low concentration of a neonicotinoid pesticide affects honeybee colony activity, but not productivity. In a 5-year study by ARS researchers in Tucson, Arizona, honeybees were fed low concentrations (5 ppb) of the neonicotinoid pesticide imidacloprid in sugar syrup; results indicated that bee colony activity was affected, but productivity was not. Treated colonies increased brood production, showed lower temperature variability and higher CO_2 production, and produced more foragers. Imidacloprid consumption did not affect adult bee numbers or average hive temperatures, and did not reduce food stores, daily food acquisition, or colony survivorship. These results suggest that imidacloprid contamination increased colony metabolism without changing colony productivity and helps explain why some studies have reported no effects, or even positive effects, of neonicotinoids on honeybee colony health. (NP305, C2, PS2A; Project No. 2022-21000-022-00D)

Novel controls for *Nosema* disease of honeybees. *Nosema* disease, caused by the fungal pathogen *Nosema ceranae*, is linked to bee colony losses worldwide and there is currently no safe and effective treatment. Iron is an essential nutrient for both the fungus and the bee and is transported by the protein *transferrin*. ARS scientists in Beltsville, Maryland, discovered that *Nosema* infection leads to elevated levels of *transferrin*, allowing the parasite to hijack the host's iron for its survival and causing iron deficiency in infected bees. Scientists then employed a genetic method to interfere with the production of *transferrin* in *Nosema*-infected bees. Results showed a reduction in iron loss and improvement in bee survival suggesting a novel and effective strategy for *Nosema* disease treatment (NP305, C2, PS2B, Project No. 8042-21000-291-00D)

<u>Insect growth regulators (IGRs) affect honeybee embryos following queen exposure</u>. Honeybees are sometimes exposed to insect growth-disrupting pesticides while foraging. ARS researchers in Davis, California, used a specialized cage design to assess honeybee queen egg production rates after exposure to IGRs. They discovered that IGRs could reduce egg hatching rates without affecting queen egg laying rates or queen survival. These results provide evidence that sublethal effects of this class of commonly used insecticide can have long-term consequences on honeybee colony performance. Understanding these sublethal effects will enable the development of management recommendations for improved risk mitigation strategies to protect pollinators and increase crop yields. (NP305, C2, PS2B, Project No. 2030-21000-053-00D)

<u>Nutrients in seasonal pollens support the annual cycle of honeybee colonies</u>. Colony losses from malnutrition could be reduced by providing pollen sources that meet the annual nutritional needs of honeybees. ARS researchers in Tucson, Arizona, identified the nutrients in spring and fall pollen and bee responses to them. Pollens were collected in Arizona and Iowa where seasonal cycles of colony growth are similar in spring and summer but differ in the fall and winter. In Iowa, brood rearing is followed by cold temperatures, leading to months of confinement in the hive. Spring pollens from Arizona and Iowa had higher levels of nutrients that support brood rearing, and bees consuming spring pollens developed larger brood food glands for feeding the queen and rearing larvae. Fall pollen from Iowa had higher levels of fatty acids and certain amino acids needed to support colonies during confinement. These findings are important for developing pollinator seed mixtures that provide pollen with required nutrients throughout the period when colonies are active, and in the formulation of pollen substitute diets that need to be specific for the season when they are being fed to colonies. (NP305, C2, PS2A, Project No. 2022-21000-022-00D)

<u>Cryopreservation of bumble bee sperm</u>. Bumble bees, which are critical pollinators of agriculturally important crops, include approximately 54 species native to North America, many of which are in decline. Despite their importance, there has been no procedure to cryopreserve their germplasm. ARS researchers in Fargo, North Dakota, achieved the first successful cryopreservation and revival of bumble bee sperm cells, resulting in 55 percent survival, a level sufficient to artificially inseminate a queen bumble bee and obtain progeny. These results will serve as a foundation for the development of protocols essential to safeguard important traits in domesticated pollinator species and to preserve the diversity of declining ones. (NP305, C2, PS2D, Project No. 3060-21220-032-00D)

Insect growth regulator (IGR) reduces sperm storage in replacement honeybee queens. The IGR methoxyfenozide is broadly used as a pesticide because it disrupts hormone balances during molting and causes mortality in lepidopteran larvae and pupae. Methoxyfenozide has low acute, or short-term, toxicity against honeybee adults, larvae, and pupae, but its long term sublethal effects against developing bees are poorly understood. ARS researchers in Tucson, Arizona, examined long-term sublethal effects of methoxyfenozide exposure via contaminated pollen and wax on rearing and production of new, or replacement, queens from worker larvae. Methoxyfenozide-exposed colonies were able to rear and support new replacement queens with similar physiological and reproductive quality and comparable survival rates as unexposed colonies. However, these queens stored less sperm in their spermathecae, or sperm storage organ, than unexposed queens. Methoxyfenozide exposure may reduce the reproductive lifespan of the queen by limiting the production of workers from fertilized eggs and lead to more frequent queen failure and replacement. (NP305, C2, PS2A, Project No. 2022-21000-022-00D)

Honeybee hives can serve as incubators to help blue orchard bees (BOBs) emerge from cocoons. BOB is an effective pollinator of early season fruit and nut crops, especially when used in combination with honeybees. The hivetop incubator (HTI) was designed and patented by collaborators as a product enabling the timely release of BOBs to pollinate spring orchard crops. Some producers have been reluctant to use these HTIs because of concern for the health of honeybee colonies that produce the incubation heat for BOB emergence. ARS scientists in Logan, Utah, found that HTIs support a quick and efficient emergence of BOBs with no loss of heat from the interior of honeybee hives. Honeybee colonies with or without HTIs remained equally healthy with no impacts on the queen, workers, or brood during the subsequent season. The results suggest that HTIs provide growers or beekeepers with a way to easily manage BOBs for pollination events, providing added confidence in getting fruit set. (NP305, C2, PS2A, Project No. 2080-21000-019-00D)

Commercial breeding improves resistance to varroa mite in honeybees. The parasitic varroa mite may be responsible for up to 50 percent of honeybee colony losses. Widespread breeding for resistance to this mite is a complex process, which has deterred adoption by stakeholders. ARS scientists in Baton Rouge, Louisiana, worked with beekeepers in Hilo, Hawaii, to develop a strategic breeding program for developing mite-resistant honeybee lines. This led to an independent commercial breeding operation in Hilo and the mass production of queens from that bee population. The roadmap established by this collaboration provides a precedent for other interested beekeeping stakeholders to develop their own breeding operations. Ultimately, breeding for desirable traits, particularly parasite resistance, will improve honeybee health and have a direct impact on global food security. (NP305, C2, PS2C, Project No. 6050-21000-016-00D)

Honeybee queen productivity is associated with a distinct hindgut microbiome. Increased queen loss has become a major concern for the beekeeping industry. ARS researchers in Tucson, Arizona, investigated queen gut microbiota and host gene expression associated with early life environments. They placed newly mated queens in either small containment cages or in normal colony environments associated with continuous egg laying. Results suggest that distinct microbiomes are associated with egg laying behavior and that these microbiotas may be signals perceived by the workers. They could also serve as a basis for a non-invasive sampling method to assess queen quality. (NP305, C2, PS2B, Project No. 2022-21000-021-00D)

<u>Climate change may exacerbate the threat of biological invasions by introduced bee species</u>. Island ecosystems may be particularly sensitive to the combined effects of climate change and biological invasions. In Hawaii, there are 21 non-native bees that have the capacity to spread pathogens and compete for resources with some 60 native bees to Hawaii. ARS researchers in Logan, Utah, modeled the predicted distributions for eight non-native bee species in Hawaii across the islands under current and future predicted climate conditions. Although the models predict expansion of the invasive bees into higher elevations under 2070 climate scenarios, areas below 500 meters in elevation were predicted to maintain their species richness. These models have the capacity to inform management decisions by federal and state stakeholders for non-native bees in Hawaii by assessing risk of invasion into new areas around the archipelago. (NP305, C2, PS2B, Project No. 2080-21000-019-00D)

<u>Insights into the systematics and evolution of brood parasitic bees</u>. Brood parasites, also known as cleptoparasites, represent a substantial fraction of global bee diversity; the oldest and most species-rich parasitic group is the Apidae subfamily *Nomadinae*. Family relationships among brood parasitic species both within and outside the *Nomadinae* have not been well studied. Using genomic sequence data, ARS researchers in Logan, Utah, and U.S. and European collaborators conducted the most comprehensive genetic analysis of this bee group to date, identifying family relationships and evolutionary patterns among 114 species. In addition to improving the taxonomy of the *Nomadinae*, this work contributes to the understanding of the group's host-parasite associations, and provides a strong framework for future bee ecological, agricultural, and conservation-related research. (NP305, C2, PS2C, Project No. 2080-21000-019-00D)

<u>Flowers as hubs for the microbial symbionts of bees</u>. Native bees are important for cranberry pollination and the role of floral substrates as the 'hub' of microbial transmission among native bee fauna has been a focus of investigation by researchers. The survival of native bees depends on microbial symbionts within the pollen provision. Microbes are critical to the development of bee larvae, but the various mechanisms and key players have not been explored. ARS scientists in Madison, Wisconsin, showed that flowers serve as the pick-up and drop-off sites for beneficial bacteria and yeasts. Microbial communities pre-digest the pollen grains within the larva's pollen provision. These symbiont microbes function much like those within the rumen of a cow, providing access to amino acids and lipids that would otherwise be unavailable to young developing bees. ARS scientists showed that these microbial communities are not specific to certain bee species, but rather are shared widely throughout bee species. The mechanisms of transmission are mediated by flowers in the landscape and ensure that critical microbial groups are harbored long enough to be broadly distributed among pollinator populations. This work is critically important for agriculture because pollinators are essential to fruit set and

development. (NP301 but relates to bee program in NP 305, C2, PS2D, Project No. 5090-21220-004-00D)