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AGRICULTURAL RESEARCH SERVICE

NATIONAL PROGRAM 305
CROP PRODUCTION

ANNUAL REPORT FY 2009





National Program 305
CROP PRODUCTION
FY 2009 Annual Report

Introduction

National Program 305 – Crop Production – supports research to develops 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 produce and market agricultural products – including food, fiber, flowers, industrial products, and fuels – profitably, while at the same time enhancing the natural resource base upon which crop production depends. This 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, thus requiring an equally diverse array of solutions.

Contemporary cropping enterprises are complex and depend on highly integrated management components addressing crop production and protection, resource management, mechanization, and automation. U.S. annual, perennial, and greenhouse (protected systems) crop production are all based on the successful integration of these components. The development of successful new production systems requires a focus on new, as well as 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 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, through conventional, organic, or controlled environment strategies. Additionally, adaptation and/or 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 honey bee (*Apis*) 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 a multitude of crops. Also, as new crops or niches are introduced, there is an increasing need for non-*Apis* bee pollinators for specific crops or protected environments.

NP 305 draws heavily on 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, with several sub-components under each:

- **Component 1:** Integrated Sustainable Crop Production
  Subcomponent 1A: Annual Cropping Systems
  Subcomponent 1B: Perennial Crops
  Subcomponent 1C: Greenhouse, High Tunnel, and Nursery Production Systems

- **Component 2:** Bees and Pollination.
  Subcomponent 2A: Honey Bees [*Apis*]
  Subcomponent 2B: Non-*Apis* Bees

Below are National Program 305 accomplishments from fiscal year 2009, grouped by research component. This report is not intended to be a progress report describing all of the on-going research, but rather a listing of accomplishments for the fiscal year, some of which are based on multiple years of research. As a result, not all research projects will reach an "accomplishment" endpoint each year.

ARS welcomes your input regarding our on-going research programs. If you have any questions as you read the report below, please do not hesitate to contact either the co-leaders for NP 305, Kevin Hackett (Kevin.Hackett@ars.usda.gov) or Sally Schneider (Sally.Schneider@ars.usda.gov) or the researchers conducting the work.

Component 1: Integrated Sustainable Crop Production

ANNUAL CROPPING SYSTEMS – STRAWBERRIES

- *Improved strawberry transplant production increases propagation efficiency and field performance.* The optimum time to establishing short-day strawberries in the mid-Atlantic coast region annual plasticulture for spring fruit production is from late August to early September. However, transplants are not available at this time in large quantities and transplants prepared by using the conventional protocol do not flower in fall. ARS scientists at Kearneysville, West Virginia, demonstrated that when plug transplants were prepared in early July instead of in early August, early fall flowering capacity of several short-day varieties increased by 400 percent. These results improve the grower's ability to double crop strawberries in fall and spring.

- *Nitrogen fertilizer affects severity of anthracnose crown rot disease of strawberries.* Anthracnose crown rot is a serious disease which often kills strawberries in the southern United States. ARS scientists at Poplarville, Mississippi, determined that plants receiving 160 ppm nitrogen had higher disease severity ratings than plants receiving 0 or 40 ppm nitrogen. Among plants receiving 160 ppm nitrogen, those treated with calcium nitrate had the least disease. When nitrogen fertilizer is applied to strawberry plants as calcium nitrate, anthracnose crown rot

severity should be less severe than when nitrogen is applied in ammonium forms. The results show that the form and rate of fertilizer may have a significant impact on the severity of diseases such as anthracnose crown rot of strawberry.

- *Regulation of fall flowering in short-day type strawberry cultivars reduces labor costs*. The labor for removing flowers on nursery plants by hand costs about $500 per acre. 'Strawberry Festival' transplants were produced from runner tips that were harvested in early July and plugged into small rooting containers by ARS scientists at Kearneysville, West Virginia. Transplants that were left uncovered started flowering in late September and more than 90 percent had bloomed by November. Transplants that were under red and blue net for the month of August did not reflower until early January. The results of this study showed that a simple change in greenhouse management can delay bloom by several months, reduce production costs and increase grower profits.

ANNUAL CROPPING SYSTEMS – COTTON

- *Airborne imaging system detects root rot in cotton fields.* ARS scientists at College Station, Texas, integrated a multispectral camera with specifically designed camera controls to develop a cost-effective airborne remote sensing system for detection of disease states/pest infestations in growing crops. The system consistently produced precise and easily interpretable images of the seasonal spread of root rot in a commercial cotton field. Through the rapid identification of this disease from an aerial platform, the area could be treated to limit the crop damage. This accomplishment provides new technology for more efficient detection and assessment of disease/pest infestation status in important U.S. crops, which will greatly aid growers and aerial applicators in protecting crops in an environmentally sensitive manner.

- *Multispectral optical sensor detects spider mite damage in cotton.* Spider mites have become key pests of cotton and can completely defoliate a crop, but recent advances in portable optical sensors may provide a tool that growers and crop consultants can use to combat this menace. ARS scientists at College Station, Texas, evaluated a commercially available optical sensor marketed to determine crop fertilizer needs to determine its potential effectiveness to detect and quantify spider mite damage in cotton**.** The sensor accurately detected mite damage within three days of mite infestation. These results provide crop consultants, growers, and others with information on a relatively low-cost and highly portable technology to detect spider mite infestations in cotton fields and make the appropriate spray application to limit the damage to the crop from the mites. Information provided by the sensor will permit use of site-specific control measures that target only appropriate areas within the larger field, which will improve control efficiency, minimize costs, and minimize environmental effects**.**

PERENNIAL CROPS – GRAPES

- *Foliar applications of phosphorus fertilizer in vineyards have little impact on vine physiology or fruit quality.* Foliar application of phosphorus fertilizers is a common practice in western Oregon vineyards. ARS scientists at Corvallis, Oregon, in cooperation with industry, determined that foliar phosphorus applications had no effect on growth, yield, fruit quality, or drought stress of vines. These results indicate that there is little benefit to applying phosphorus fertilizers, even in low phosphorus vineyards, and that potential risks of phosphorus runoff (ground water contamination) or reduced *arbuscular mycorrhizal* fungi function appear to

outweigh any benefits of using foliar phosphorus. Findings from this study provide the basis to eliminate application of foliar phosphorus fertilizers in vineyards, thus increasing profitability and reducing environmental impact.

- *Colonization of roots by arbuscular mycorrhizal fungi enhanced by reduced irrigation.* Regulated deficit irrigation (RDI) is used in irrigated vineyards to control canopy growth and improve fruit quality, but little is known about how imposed deficits alter root growth and beneficial mycorrhizal symbionts. ARS researchers at Corvallis, Oregon, and industry collaborators determined that fine root growth was reduced by both 50 percent RDI treatments, but this was countered by increased colonization of roots by *arbuscular mycorrhizal* fungi. Irrigation did not affect yield or quality of grapes produced, even though whole plant photosynthesis was reduced in both 50 percent RDI treatments. These results indicate that high quality grapes can be produced with less water than the current RDI practice because of greater colonization by symbiotic fungi at lower water levels.

- *Cover crops have no effect on beneficial grapevine root microbes.* There is a need to determine if cover crops can be used to enhance grapevine nutrition, specifically by increasing populations of beneficial *arbuscular mycorrhizal* fungi (AMF) that are critical for grapevine nutrition because they increase uptake of the nutrient phosphorus from the soil. ARS scientists at Davis, California, examined grapevine AMF in the presence of two cover crop treatments (rye, triticale) that hosted some of the same AMF species as grapevines and, thus, were expected to increase populations of AMF in the vineyard. Despite the greater abundance of mycorrhizal plants in the vineyard with the cover crops, there were no increases in AMF in grapevine roots. This research suggests that planting cover crops that host the same AMF as grapevines is unlikely to increase AMF in grapevines.

- *Grapevine rootstocks host different soil microbial communities.* Rootstocks have a significant effect on important characteristics of grape production (e.g., vigor, yield, fruit and wine quality, mineral nutrition, pathogen resistance, and drought tolerance), and differences in such characteristics among rootstocks may, in part, be attributable to differences in their soil microbial communities. ARS scientists at Davis, California, identified significant differences in the structural and functional diversity of the microbial community colonizing the different rootstocks, both within roots and on their surfaces. As many of the soil microbes are critical for nutrient cycling, their further characterization and association with specific nutrient pathways will allow growers to develop sustainable fertilization and irrigation programs with a better understanding of the biological component.

- *Dynamic crop monitoring and yield estimation.* Transient and long-term labor shortages in U.S. agriculture require innovative, automated approaches to production practices that long have been manually accomplished in specialty crops. Work conducted by ARS scientists in Corvallis, Oregon, addressed the juice grape industry's need for an automated alternative to the labor-intensive practice of estimating yield from grape samples collected by hand. The Trellis Tension Monitor (TTM) that was developed over several years for tracking crop growth and estimating yield in trellised crops, specifically grapevines, was shown in FY 2009 to outperform the commercial yield estimation technique used by major juice processors. The TTM

technology can be applied by juice processors or wineries as a stand-alone, remote yield estimation technique and as a decision aid to confirm desired levels of fruit thinning or to target the timing of hand sampling for supplemental, traditional yield estimation approaches.

- *Water use by grapevines measured accurately by a novel dual heat pulse sap flow sensor.* With impending limits on irrigation water in California and other arid grape growing regions of the United States, growers need to more accurately measure water use by grapevines to irrigate more efficiently. ARS scientists at Davis, California, developed a novel sap flow sensor that is based on two existing heat pulse techniques. The sap flow sensor accurately detected changes in water use with various rates of irrigation and responded quickly to changes in water demand imposed by shading. With integration into real time irrigation systems, the sap flow sensor will help growers conserve irrigation water by applying the exact amount needed.

- *Proteins in grapevine roots are markers of water uptake.* Breeding programs are currently focusing on drought-tolerant grapevines, but there is no convenient means of assessing drought tolerance other than growing plants in the greenhouse and field, and evaluating their response to minimal irrigation. ARS scientists at Davis, California, examined levels of the proteins in grapevine roots that facilitate water movement (aquaporins) to determine if they respond consistently to known quantities of water and, thus, to evaluate aquaporin production as an indirect method of measuring drought tolerance. Aquaporin production was highest in drought-resistant rootstocks and lowest in drought-susceptible rootstocks. This knowledge will advance breeding programs by accelerating the process of evaluating new grapevine varieties for drought-tolerance.

PERENNIAL CROPS – CRANBERRIES/BRAMBLES

- *Kaolin clay-based product controls weeds in bramble production*. Weed management is an important component of small fruit cropping systems. If left unchecked, weeds will compete with blackberry transplants for soil resources and adversely affect plant productivity. ARS scientists, in Kearneysville, West Virginia, determined that incorporation of hydrophobic kaolin into cultivated soil after planting suppressed weed growth for 3 years without affecting blackberry productivity. A patent was filed to protect this technology. This kaolin clay and soil combination increases the arsenal of products for managing weeds in horticultural crops.

- *Winter protection techniques reduce bud damage in blackberries.* There is a need to develop alternative methods of reducing winter injury in blackberries. The rotating cross arm trellis and cane training technique were modified by ARS scientists at Kearneysville, West Virginia, so that canes of 'Siskiyou' and 'Boysenberry' trailing blackberries could be rotated and positioned near the ground in winter. By positioning the canes near the ground, the application of spun-bonded polyester floating row cover over the plants was made simple. Under the cover air temperature was 7 degrees C warmer during several cold nights than in the open and did not drop below the lethal temperature. Water loss in canes was reduced by covering them with floating row cover. More than half of flower buds on plants that were covered showed no winter damage, while plants in the open suffered more than 90 percent bud kill. These results will lead to the expansion of blackberries into areas with more severe winter conditions.

- *Root chilling increases blackberry productivity.* ARS scientist in Kearneysville, West Virginia, demonstrated that it was necessary for the root system of pruned primocane-fruiting blackberry plants growing in pots to be exposed to chill units before primocane emergence for subsequent flowering. With more than 500 chill units, cane emergence was hastened and plants bloomed in a much shorter time. These results improve the ability to crop primocane-fruiting blackberries in a serial cropping system. Also, a serial cropping system offers growers the simplicity of removing all canes after harvest and handling the pots with no above ground shoots in and out of greenhouse.

- *Best irrigation practices to maximize fruit production in red raspberry.* Good irrigation practices are critical for profitable production of red raspberry in the Pacific Northwest. However, little is known about what methods and scheduling strategies are best for irrigating the crop. In a 5-year study, ARS scientists in Corvallis, Oregon, evaluated new irrigation methods and scheduling strategies for growing red raspberry and identified practices that maximize yield and fruit quality. The guide to be published from the results will help farmers with irrigation system design and water management practices for optimal production in red raspberry.

PERENNIAL CROPS – FRUIT TREES

- *Root system characteristics improve peach tree nutrient uptake.* Adequate mineral nutrition is critical for high fruit quality and sustained yield of fruit trees. Root systems must compete for nutrients such as nitrogen and phosphorus, which are often present in low quantities in the soil. Compact peach trees with fibrous roots systems were shown by ARS scientists in Kearneysville, West Virginia, to have an advantage in absorbing nutrients, such as phosphorus, when present in low concentrations in the soil. However, under conditions of high soil fertility, the greater water movement capacity of Pillar trees supported greater nutrient uptake. Genetically-determined peach tree root growth habit affects nutrient absorption and therefore it could be a selection factor in breeding programs and soil management plans.

- *Increasing plant diversity increases ecosystem services in orchards.* Orchard-level management experiments that evaluate pesticides often do not consider effects beyond the targeted pests, missing potentially important effects on ecosystem services provided by the orchard. ARS scientists at Kearneysville, West Virginia, evaluated biological control in apple and peach orchards, with and without flowering plants, and interplanting of peach trees with apple trees. Although biological control of targeted aphids and bud moth did not increase, population levels of other pests and the percentage of fruit damaged by several insect pests were reduced by increasing plant diversity of the orchard ecosystem. Increased diversity of the orchard vegetation structure suppressed pest damage through complex functional interactions and not only by direct predator-prey or parasitoid host interactions. The ecosystem service of pest regulation was achieved indirectly through subtle changes in ecosystem processes, but this was only detected by using a holistic approach to evaluating orchard-level experiments.

- *Mechanical peach thinning equipment is developed.* Peach normally sets many more fruit than it can develop to acceptable market quality standards. Peaches currently require laborious and costly hand thinning. A spiked-drum shaker mechanism was developed by ARS scientists in Kearneysville, West Virginia, as a mechanical supplement for hand thinning in peaches. The

equipment can bloom thin or thin at the normal green fruit thinning stage. Researchers demonstrated a saving of 30 percent to 50 percent in hand thinning costs for high-density peach production systems.

- *Particle film materials reduce heat stress and increase apple productivity.* Heat stress is a limiting factor of plant productivity throughout the world and kaolin-based particle films (PF) have demonstrated that the reflective nature of the resulting plant surface can increase plant productivity primarily by reducing temperature in fruit, leaf, and canopy, but the underlying plant responses are not clear. ARS scientists in Kearneysville, West Virginia, demonstrated that seasonal water use of apple is better evaluated with stable isotope discrimination that integrates seasonal variation, rather than the use of whole canopy gas exchange measurements that measure water use for brief periods of time. Use of a 3 percent particle film treatment in an irrigated orchard resulted in lower water use due to increased stomatal conductance from lower canopy temperature and increased light diffusion that increased photosynthesis. In 'Empire' apple, photosynthesis and productivity can be increased with particle film and irrigation treatments but at the cost of decreased water use.

PERENNIAL CROPS – NUT TREES

- *Partitioning of nitrogen by pecan trees.* Nitrogen management is a major, and increasing, cost for pecan farmers. ARS researchers at Byron, Georgia, found that trees maintained with adequate nitrogen nutrition derive the majority of the nitrogen used for annual growth from nitrogen stored from the previous season. This finding explains why trees require at least 2 years response to changes in nitrogen management. The results emphasize the importance of maintaining an annual nitrogen fertility program for current and future production.

- *Increasing Pecan Crop-load and Yield.* Excessive crop loss due to fruit-drop can greatly reduce profitability of certain orchard operations. A commercialized natural growth regulator product marketed for prevention of premature apple drop in the fall was demonstrated by ARS researchers at Bryon, Georgia, to have potential to reduce nut-drop of certain pecan cultivars; thus increasing yield. The researchers determined that this material, ReTain, could be a useful horticultural tool for managing crop load on certain sensitive pecan cultivars; thus, providing farmers with the means to avoid excessive spring fruit-drop**.**

- *Reducing alternate bearing by using gibberellic acid to increase tree resistance to black pecan aphids.* Enhanced alternate bearing, and subsequent reduced profitability, is greatly accentuated by stress factors triggering premature senescence of canopy foliage or of premature defoliation. ARS researchers in Byron, Georgia, found that treating canopies with gibberellic acid, a naturally occurring plant product, prevents black pecan aphids from being able to trigger senescence of foliage or damage to tree canopies and also keeps populations of black pecan aphids from building to damaging levels in orchards. The approach offers a novel tool for controlling alternate bearing inducing black pecan aphid populations by treating canopies with a natural product growth regulator. This new tool has potential for use on all crops affected by senescence inducing aphids.

- *Identification of factors that lead to nickel deficiency in plants.* The expression of nickel deficiency by plants is a mystery when plants and soils contain what appears to be plenty of nickel to satisfy crop needs. ARs scientists at Byron, Georgia, found that expression of nickel deficiency depends largely upon the relative concentrations of zinc and/or copper in crop tissues and organs, thus affecting the biological availability of nickel for plant processes. This research demonstrates that nickel deficiency is probably more common for agricultural crops than widely thought and that excessive agricultural usage of zinc or copper fertilizers can potentially trigger nickel deficiency.

- *Improved boron and nickel management reduces pecan crop loss to water-stage-fruit-split.* Crop loss to water-stage-fruit-split is a major cause for crop loss in certain pecan cultivars. ARS researchers at Byron, Georgia, found that the incidence of this form of loss is reduced by timely improvement of tree nutritional status for boron and nickel. The work demonstrates that orchard yield can be increased by improving tree nutritional status for boron and nickel.

- *Mechanized hedge pruning as a light management tool for pecan in the Southeastern United States.* Orchard crowding, with an associated loss of nutmeat yield and increase in alternate bearing, is a major problem for many pecan farmers. ARS scientists demonstrated that several mechanized hedge pruning strategies were tested in the relatively low sunlight southeastern United States could increase light, fruiting, and yield. Results support the notion that hedge pruning can work in low sunlight regions, if done properly. The work supports the use of mechanized hedge pruning in the southeastern United States as a viable light and canopy management tool.

PERENNIAL CROPS – TROPICAL CROPS

- *Host status of mamey sapote germplasm to Anastrepha obliqua. Anastrepha obliqua*, a fruit fly, is not present on the mainland and, if established there, could pose a serious threat to North American agriculture. ARS scientists in Mayaguez, Puerto Rico, established the host status of mamey sapote to the fruit fly *Anastrepha obliqua* by collecting close to 1,000 fruits from the field and monitoring them for fly infestations. Fruit exposed to female flies under rigorous conditions did not become infested. These results indicated that the risk of transporting Anastrepha obliqua fruit flies in shipments of mamey sapote is highly unlikely. There is a ready market for mamey sapote in the United States and growers in Puerto Rico would like to be able to export their products to the United States.

- *Integrated pest management of Phyllophaga vandinei. Phyllophaga vandinei* is a key pest of fruit trees; the adult beetles defoliate the trees and the larvae feed on the roots. ARS scientists from Mayaguez, Puerto Rico, in collaboration with Cornell University, were able to identify the sex pheromone produced by the female and demonstrated that traps baited with this pheromone, if properly placed, attracted significantly more males than similar traps without the pheromone. They also have successfully infected adults and larvae of this beetle with an iridovirus. Adults and larvae can be infected by direct injection of the purified virus and by exposure to soil that contained infected individuals more than two weeks prior. The scientists determined that the frass of infected individuals contain the virus, suggesting at least one route of infection.

Mortality was low (less than 30 percent), but the mode of infection suggests that the virus could be engineered or optical brighteners could be used to increase the virulence and the virus can easily be delivered to target populations in the soil.

- *Effect of adult and larval Phyllophaga vandinei feeding on mamey sapote yield.* May beetles (*Phyllophaga vandinei)* can severely defoliate fruit trees, such as mamey sapote, and the larvae feed on the roots. The sheer numbers can frighten growers and lead to unwarranted pesticide applications. Although young seedlings are very susceptible to defoliation and root-feeding by May beetles, ARS scientists in Mayaguez, Puerto Rico, found that there is no correlation between the fruit yielded by a tree (number of fruit and weight) and the abundance of May beetles feeding on the foliage and the roots of these trees. Indeed, mature trees can harbor up to 300 individual adults without a decrease in yield. This information will enable growers to avoid the unnecessary application of pesticides and reduce the human and environmental risks pesticides pose.

- *Description of the fungus Dolabra nepheliae on rambutan and lychee.* Fungi are a large and diverse group of organisms that cause serious diseases of crop and forest plants. Accurate knowledge of fungi is critical for controlling the diseases they cause. Rambutan and lychee are tropical plants that produce delicious edible fruits, but a little known fungus causes a canker disease of rambutan and lychee in Hawaii and Puerto Rico known as corky bark disease. ARS scientists at Mayaguez, Puerto Rico, described and illustrated the fungus causing this disease and determined its relationship to other disease-causing fungi. This research will help plant pathologists accurately identify the cause of this disease of specialty crops. Knowledge of this fungus will be useful to plant regulatory officials working to control the spread of this disease.

- *Sugarcane yield monitor predicts field cane yields.* Louisiana sugarcane producers continue to search for ways to increase yields and profitability. One way to increase profitability would be to accurately predict and map cane yields at harvest so that transportation costs could be minimized and in-field variability could be more effectively managed. In a cooperative research effort, ARS scientists in Houma, Louisiana, worked with a Kansas State University Agriculture Engineer to develop and test an optical yield monitor to predict cane yields under field harvest conditions. Results demonstrated there was a linear relation between the optical sensor response and actual cane yields. The yield monitor was not influenced by variety or harvester speed and appeared to require minimal maintenance. This technology will allow sugarcane producers to map within field variability, identify areas requiring additional inputs, and help to maximize transportation efficiency.

- *Fruit quality traits and yield of carambola genotypes grown at three locations.* Nine carambola (*Averrhoa carambola*) genotypes grown on Oxisol, Ultisol, and Mollisol soils were evaluated for 4 years under intensive management at Isabela, Corozal and Juana Díaz, Puerto Rico, respectively. ARS scientists at Mayaguez, Puerto Rico, determined that there were no significant differences in number and weight of marketable fruits per hectare. There were no significant differences in weight of marketable fruit per hectare among cultivars B-17, Thai Knight, and Sri Kembangan between locations. The average marketable fruit weight for these higher yielding cultivars was 36,060 kg/ha. Arkin and B-16 were the lowest yielding cultivars averaging 23,490 kg/ha of marketable fruits. Cultivar Kari produced significantly longer fruits

at all locations, whereas cultivar B-16 produced the shortest fruits. Significantly higher brix (sweetness) values were obtained from fruits of cultivar B-17 at all locations whereas lower values were obtained from those of Arkin.

- *Rambutan resistance to acid soils.* The most productive soils of the world are already under cultivation, and those available for agricultural expansion are often strongly acid, possessing toxic levels of soil aluminum (Al) and/or manganese (Mn). These elements could drastically reduce crop yield when present in the soil at high concentration. In a 2-year field study, ARS scientists at Mayaguez, Puerto Rico, determined that high levels of soil acidity did not affect growth and dry matter production of seedlings of four rambutan cultivars. These results demonstrate that rambutan is highly tolerant to acid soils and that tolerance may involve a physiological process to keep Al and Mn from entering the roots. This study provides useful information to growers and extension personnel about the adaptability of rambutan to acid soils.

SPRAY APPLICATION TECHNOLOGIES

- *Scanning system to optimize pesticide spray applications.* Inaccurate application of pesticides on target areas can cause serious spray drift and off-target loss problems, resulting in inefficient pesticide use, food safety concerns, environmental contamination and hazards to workers. A portable scanning system, DepositScan, was developed by ARS scientists at Wooster, Ohio, to quickly evaluate the deposition quality of pesticide spray applications. The software for DepositScan is available to the public without charge, and can be downloaded from the Web site: http://ars.usda.gov/mwa/wooster/atru/depositscan. DepositScan is a tool that farmers can use to optimize equipment settings, techniques, and practices. For extension educators, DepositScan can help train applicators to accurately apply chemicals on targets. For manufacturers, it can accelerate the process for new pesticide formulations and pesticide spraying equipment. Long-term benefits of DepositScan will be to minimize off-target loss including spray drift, and increase pesticide spray application efficiency and efficacy.

- *Potentially devastating soybean disease could be kept in check with new information on application technology.* Asian soybean rust is a potentially devastating disease that could destroy much of the U.S. soybean crop. Current fungicide treatments can manage soybean rust if the treatments can reach the lower part of a mature soybean canopy. Field studies conducted by ARS scientists at Wooster, Ohio, demonstrated that small droplet applications designed to improve coverage can only effectively treat the target area if air-assistance is used to help provide extra energy to penetrate the canopy. These findings demonstrate the importance of matching the application equipment parameters with the pesticide choice to provide the most efficacious applications.

- *Improved spray drift reduction technologies.* With increasing environmental awareness and associated concerns with potential off-target movement of applied crop protection products, aerial applicators will soon be facing pesticide label-enforced buffer zones. These buffer zones potentially reduce the treatable area of crop production fields by requiring field-edge strips that remain untreated in an effort to increase the downwind distance from the application swath to the field edge. New technologies are needed that will reduce spray drift from aerial and ground application as compared to conventional application systems. In cooperation with the U.S. EPA Office of Pesticide Programs, ARS scientists in College Station, Texas, provided definitive

assessments of protocols that can be used to test potential drift reduction technologies (DRTs). The work also involved both low- and high-speed wind tunnel testing protocols for ground and aerial DRTs, including assessments of various spray nozzles and the droplet sizes produced. This accomplishment is critical in providing the aerial application industry with scientifically sound information, protocols, and new technology to assure ongoing compliance with evolving regulatory requirements.

- *New spray nozzles improve herbicide application efficiency.* The broad-spectrum herbicide glyphosate is widely used for weed control in genetically engineered glyphosate-resistant crops such as cotton, corn, and soybeans. Due to the rising cost of glyphosate, aerial applicators need new spray technologies that will allow them to optimize the efficiency of spray applications so that effective weed control can be achieved with a minimum amount of glyphosate. ARS scientists at College Station, Texas, developed definitive deposition/efficacy information on glyphosate sprays applied through conventional hydraulic nozzles, as compared to new rotary atomizer and electrostatic nozzle technology. The work clearly showed that the new nozzles are superior in many respects, including increased herbicide efficacy. The reduced amounts of liquid spray required permits significant reduction in aircraft energy consumption and application time, resulting in lowering of application costs and enhancement in environmental sensitivity.

- *Optimizing pesticide application rate technology for nursery production.* Use of traditional settings in air-assisted sprayers in nursery applications resulted in excessive spray deposition inside tree canopies and loss of spray mixtures to the ground and air. Various adjustments of air-assisted sprayers developed by ARS scientists at Wooster, Ohio, resulted in half the usage of pesticides for pest and disease controls in nursery shade tree plants. By using the half-rate technology, growers safeguarded the environment due to pesticide applications and reported savings of over $200-$500 per acre.

GREENHOUSE, HIGH TUNNEL, AND NURSERY PRODUCTION SYSTEMS

- *Predisposition of trees to infection by Phytophthora syringae.* It is unknown whether the increased incidence of *Phytophthora syringae* during the dormant period is due more to the wet-cold environment or the dormancy status of the tree. In cooperation with researchers at Oregon State University Trees, ARS scientists in Corvallis, Oregon, determined that environmental conditions, particularly temperature, after exposure of pear trees to the pathogen are important for disease development regardless of tree growth stage. Disease caused by *P. syringae* is common on bareroot deciduous nursery stock in the U.S. Pacific northwest and requires intensive cultural and chemical management. These results will be useful to nursery managers and extension personnel in areas infested with *P. syringae* and highlight the importance of inspection and treatment of both dormant and actively growing trees to prevent or reduce the spread of plant diseases in nursery stock.

- *Factors controlling Sudden pH Decline in greenhouse crops determined.* When crops such as geranium and marigold are grown in containers in a greenhouse setting, growers have noticed that in a matter of a few weeks, the pH of the root zone declines two to three units. This condition, called Sudden pH Decline (SPD), leads to loss of crop quality or total crop failure. While it is linked to some specific crop types, the basic cause of SPD was not known. In a

cooperative project, ARS scientists at Wooster, Ohio, found that low phosphorus, high light, and high temperature by themselves and in concert with one another, can lead to SPD. In each case, the nutrient/light/temperature stress shifts the ratio of uptake of nitrate and ammonium forms of nitrogen to more preferentially ammonium uptake. This results in more acidification of the root zone. With this information, growers can better avoid the environmental conditions that lead to this situation; can more appropriately supply these crop types with phosphorus, nitrate, and ammonium; and take comprehensive corrective action (management of environment and fertility) when faced with the condition. Breeders could also apply these environments during crop breeding and selection to identify germplasm that is more resistant to SPD.

- *Chemical compounds for controlling Botrytis infection.* Infection by the fungus *Botrytis cinerea* is one of the most common and elusive pathogen problems in postharvest ornamentals. A range of compounds including environmentally-friendly oxidizers, such as benzoic acid, chlorine dioxide, and hydrogen peroxide, were evaluated by ARS scientists in Davis, California, as postharvest dip treatments for the control of *Botrytis cinerea* infection on cut rose flowers. Several highly promising fungistatic compounds such as a chlorine-based oxidizer were identified with potential to control Botrytis disease on cut rose flowers. Dipping rose flowers in the oxidizer significantly reduced Botrytis development. In other studies, the scientists found the efficacy of fungicides to prevent Botrytis infection on rose flowers was greatest when fungistatic compounds were applied about 6 hours after harvest. These results highlight the potential of this simple and safe biocide and the importance of treating the fungus at its most vulnerable development stage for reducing postharvest Botrytis infection on rose flowers.

- *Extending the life of cut flowers.* The failure of some cut flowers to open fully after dry transport and storage is a major postharvest problem. The marketability of these flowers is also limited by their short display life. Thidiazuron (TDZ) is a potent inhibitor of leaf senescence in cut flowers. ARS scientists in Davis, California, found that a postharvest pulse with TDZ or TDZ containing formulation extended life of Iris and Bird-of-Paradise flowers. These findings highlight the potential use for TDZ as a postharvest treatment to improve the opening and longevity of cut flowers.

- *Spraying hydrangea leaves in the autumn alters defoliation efficiency, growth, and flowering characteristics.* Chemical defoliation and growth regulators commonly used during the production of florists' Hydrangea can decrease product quality. In cooperation with researchers at Mississippi State University, ARS scientists in Corvallis, Oregon, determined optimal concentrations for use of defoliants on florists' hydrangea at different times in the autumn and found spraying foliage with urea in the autumn can ameliorate some of the negative effects of defoliants and growth regulators on performance during forcing. Predictable plant response during forcing is important for producing high-quality herbaceous perennial plants at an acceptable cost. These results may be used by growers and extension personnel to develop alternative nitrogen management strategies for production of herbaceous perennial nursery crops that improve product quality, decrease production costs, and encourage use of environmentally sustainable practices.

- *Nitrogen form in fertilizer alters cold hardiness of nursery trees.* In cooperation with researchers at Mississippi State University, Oregon State University, and Washington State University, ARS scientists in Corvallis, Oregon, determined that both nitrogen rate and nitrogen form influenced cold tolerance of buds and stems of green ash (*Fraxinus pennsylvanica*) in both autumn and winter. Trees with a similar nitrogen status can withstand different levels of cold depending on the type or form of fertilizer applied. Consequently, fertilizer selection may be important when developing nutrient management strategies for production of container-grown nursery crops in climates prone to winter injury especially since shoot dieback can decrease salability of nursery trees. The results of this research will be used by growers, fertilizer manufacturers, and extension personnel to increase profitability of commercial nursery trees by developing fertilizer management strategies that strive to improve plant quality for nursery stock prone to winter injury.

- *Foliar sprays with urea and defoliants in the autumn do not increase tree susceptibility to infection by Phytophthora syringae.* Disease caused by *Phytophthora syringae* is common on bareroot deciduous nursery stock in the Pacific Northwest and requires intensive cultural and chemical management. ARS scientists in Corvallis, Oregon, determined that spraying trees in the autumn with urea, defoliants, or fungicides such as PhytoFOS or Alliette influenced tree nitrogen status, but was unrelated to susceptibility to *P. syringae*. These results will be useful to nursery managers and extension research in areas infested by the pathogen.

- *Elimination of Rhizoctonia from azalea stems used for propagation.* The pathogen that causes web blight on azalea, *binucleate Rhizoctonia*, is carried on healthy appearing stems used to propagate next year's crop. The pathogen annually damages about 30 percent of the azalea cultivars commonly grown. ARS scientists in Poplarville, Mississippi, in cooperation with Mississippi State University scientists, developed methods that will eliminate *Rhizoctonia* species from azalea stems collected for propagation. Submerging stems in 122°C water for 21 minutes eliminated the pathogen from the stem with only minor damage that would not hinder rooting success. This research is one component of an integrated control approach and a critical first step in minimizing the spread of this pathogen in the azalea crop. The control strategy will reduce crop damage, minimize fungicide usage, while improving crop yield potential.

- *Control of foliar diseases in the greenhouse using hydrogen dioxide.* Commercial ornamental plant producers commonly use products containing hydrogen dioxide that have an EPA registration for application on plants, yet published efficacy data shows that products are ineffective. ARS scientists in Poplarville, Mississippi, showed that hydrogen dioxide can control foliar disease in greenhouse produced ornamental crops when applied on plants a minimum of 3 to 5 times per week to prevent development of daylily rust. This research provides knowledge about how to use an environmental friendly product to achieve disease control comparable to standard fungicide products.

- *Virtual Grower 2.5 released.* Growers of greenhouse crops face many complex, interrelated systems on a daily basis wherein one decision influences others in sometimes counterintuitive ways. Virtual Grower software developed by ARS scientists at Wooster, Ohio, allows users to build virtual greenhouses with many different types of materials, select from different fuel types, simulate heating needs and costs, and see the impact of those decisions on the growth and

development of some commonly grown greenhouse crops. This version of the program has added supplemental lighting, several more crop species, the ability to add more fuels and materials for testing, improved calculations for energy curtains, and real-time weather "calls" in which the next 2 days of weather at a grower's U.S. site can be simulated within the model. This software has assisted both large and small growers to identify energy (and money) saving strategies in their operations, improved efficient scheduling of crops, and helped growers obtain energy efficiency improvement grants through various funding sources.

- *A novel dual heat pulse sap flow sensor for accurately measuring water use by grapevines.* With impending limits on irrigation water in California and other arid grape growing regions of the United States, growers need to more accurately measure water use by grapevines to be able to irrigate more efficiently. ARS scientists at Davis, California, developed a novel sap flow sensor that is based on two existing heat pulse techniques. The sap flow sensor accurately detected changes in water use with various rates of irrigation and responded quickly to changes in water demand imposed by shading. With integration into real time irrigation systems, the sap flow sensor will help growers conserve irrigation water by applying the exact amount needed.

- *Biofuel crops nursery potting substrates.* Pine bark is the primary component of nursery potting substrates. Due to the energy and economic crises, pine bark availability has declined and price has increased dramatically, negatively impacting the ability of U.S. nursery growers to secure a reliable substrate for growing plants. Research by ARS scientists at Wooster, Ohio, showed that several biofuel crops already grown in the United States (willow, switchgrass, and giant miscanthus) can be used as a substitute for pine bark. This will provide an additional market for biofuel crop producers, while reducing nursery grower dependency on pine bark.

- *Functional analysis of regulatory genes associated with flower senescence and abscission by Virus-Induced Gene Silencing.* ARS scientists in Davis, California, used virus-induced gene silencing (VIGS) as a tool for evaluating the possible regulatory role of a number of transcription factors in leaf and flower senescence and abscission. The genes encoding transcription factors were identified from a public database and cloned from cDNA libraries of petunia and tomato. The time to pollination-induced petal wilting was increased by silencing a petunia homolog of a MADS-box gene while silencing of NAC type of transcription factors accelerated flower senescence. These results suggest the possibility that, as in leaf senescence, floral senescence is the result of a regulatory network. Our research will benefit the industry in the longer term, providing more effective means of increasing the vase life and reducing leaf and flower abscission.

Component 2: Bees and Pollination

BEE HEALTH

- Colony collapse disorder (CCD) is a devastating new problem for honeybees (Aphis). A CCD Action Plan was developed in 2007 by the Federal CCD Steering Committee (co-chaired by ARS and the USDA National Institute for Food and Agriculture) and is available online at www.ars.usda.gov/is/br/ccd/ccd_actionplan.pdf. A Colony Collapse Disorder Progress Report was published by the CCD Steering Committee in June 2009. It can be found at: www.ars.usda.gov/is/br/ccd/ccd_progressreport.pdf.

- *Assessment of interacting factors linked to honey bee colony collapse.* ARS researchers in Beltsville, Maryland, have led efforts to expand the search for suspects in the wide-scale loss of adult worker bees in the U.S. honey bee populations, including colony collapse disorder (CCD). Recent results include evidence that multiple viruses are associated with CCD, and that some collapsed colonies carry unusual traits including "entombed" pollen. Ongoing work is testing for links between chemical exposure and how this exposure impacts the effects of known parasites and pathogens. CCD is now believed to have multiple causes, and this work has helped identify those agents most important in this syndrome.

- ARS has initiated an Areawide Program on Bee Health with the purpose of demonstrating that good bee management can maintain healthy bees despite the pressures of CCD. This program uses ARS technologies, such as bees developed with resistance to the varroa mite, the major bee pest (which also vectors bee viruses); special protein-rich diets developed to strengthen colonies for early spring build up; biorational miticides based on bee pheromones; and other treatments to mitigate disease and reduce stress on the colonies used in migratory beekeeping.

- *Genome of the honey bee pathogen Nosema ceranae sequenced.* The prevalence and impact of nosema disease have increased dramatically in the past few years. To better understand how *Nosema ceranae*, a key fungal suspect in colony collapse disorder, affects bees, and to provide insights and tools for industry and researchers seeking to minimize the disease, ARS researchers in Beltsville, Maryland, led a collaborative project to sequence and describe the genome of this microbe. The fungus was found to have a compact genome, relying on its bee host to provide critical proteins. This and other genomics clues will be used to develop control strategies, and to provide novel genetic markers for restricting the movement of this pathogen.

- *Pathology and spread of Nosema disease.* There has been a great increase in both the range and prevalence of *Nosema ceranae*, a fungal parasite of honey bees that was only diagnosed in U.S. bees in the past 2 years. ARS scientists in Beltsville, Maryland, established that this species has been present for over a decade in the United States and conducted the first pathological analyses of this parasite. The latter study showed that *N. ceranae* is much more invasive in the body of honey bees than is the better known *Nosema apis*, moving and reproducing well beyond the gut wall. These findings were important for predicting the role of *Nosema* in colony collapse disorder (CCD) and suggest different vulnerabilities of the two *Nosema* species to environmental conditions and to the single registered product now available for their control, fumagillin.

- *Molecular assay developed to detect and quantify two nosema parasites of honey bee. Nosema ceranae*, a honey bee gut parasite relatively new to the United States, is causing increasing problems for beekeeping and may be associated with colony collapse Disorder. A genetic assay was developed by ARS researchers in Baton Rouge, Louisiana, that simultaneously detects and quantifies both *N. ceranae* and the longer known *N. apis*. The assay detects less than 10 copies of *Nosema* spp. in a single bee and may be used in place of laborious microscopic examination. The assay is being used to assess the kinetics of *N. ceranae* infestations during natural infection, and this information will be utilized for further study of stock and colony-level resistance to *Nosema* infestation and breeding for stock improvement.

- *Documentation of the annual U.S. honey bee colony losses.* ARS scientists and their partners conducted surveys in 2007, 2008, and 2009 to determine the rate of honey bee colony losses in the United States in the fall of each year. The overall losses, due to a variety of causes, averaged about 30 percent in each of the years. Individual beekeepers reported that queen failure was their number one reason for colony losses while colony collapse disorder (CCD) symptoms were reported as the number 3 cause. Beekeepers reporting CCD-like symptoms reported higher losses than those that did not report CCD-like symptoms. The overall rate of colony losses has remained steady for 3 years, and those in the beekeeping industry believe the losses to be unsustainable. ARS scientists in Beltsville, Maryland, are currently testing a means to limit the negative effects of queen loss, transportation, and other stress factors to provide solutions for beekeepers who must move bees to meet pollination demands of U.S. agriculture.

- *Simplified measures of the Varroa sensitive hygiene trait of honey bee resistance to varroa problem.* Varroa sensitive hygiene (VSH) is a trait of honey bees that supports resistance to varroa mites, but is difficult for bee breeders to measure and use in a selection program. Components of varroa sensitive hygiene were evaluated by ARS scientists in Baton Rouge, Louisiana, to identify simple methods for selection. The responses of individual colonies were evaluated when infested brood was introduced for short periods. Varroa sensitive hygiene colonies tended to uncap more infested cells after two hours, reduce mite infestation after 40 hours, and reduce infestation and mite fertility after one week. Simple, short-term measures of uncapping and of reductions in infestation and mite fertility may facilitate selection of varroa sensitive hygiene by more bee breeders.

- *Elucidating the chemistry of host finding by the varroa mite.* The varroa mite is the most important pest of the honey bee industry in the world and no highly effective control strategy exists for this pest. To develop a non-pesticide approach to control of the mite, ARS scientists investigated the semiochemical communication system used by the mite to invade honeybee larval cells. Two chemicals were identified that effectively causes mites to be attracted into empty rearing cells and keeps the mites from leaving the cells and another that repels mites. Identification of these compounds makes development of an effective non-pesticide method for control of the mite possible.

- *Miticide cure for varroa mite of bees can cause bee death if bees are weak.* Bees infected with varroa mites often show high mortality during the first 72 hours after being treated with a strong miticide. ARS researchers at Weslaco, Texas, found that colonies with high levels of mites should be treated with a mild miticide first, because a strong miticide may actually kill bees already weakened by the mites. Only after colonies are on the way to recovery and mite levels, while still serious, are not colony threatening, should stronger miticides be used. It is likely that this finding may also be applied for other stressors as well; e.g., a pesticide spray on a pollinated crop is likely to kill more bees in colonies whose health is compromised in some way.

- *New miticide kills bees when combined with common fungicide.* Almond growers apply fungicides to prevent blossom rot when rainy, moist conditions are expected. One of the more commonly used fungicides for this is Vanguard. ARS scientists at Weslaco, Texas, determined that Vanguard interacts with the active ingredient in Hivastan (fenpyroximate), a newly registered product for the control of the varroa mite, the most important honey bee parasite and

a likely key contributor to colony collapse disorder. The miticide-fungicide interaction may be a cause of bee mortality. This finding suggests that almond growers should work with beekeepers in developing coordinated pest management strategies.

- *Small hive beetle as a pest and vector.* The small hive beetle is a parasite and scavenger of honey bee colonies, and because it feeds and moves within honey bee colonies, it has the potential to act as a vector to transmit pathogens from infected bees to healthy bees. ARS scientists in Beltsville, Maryland, in collaboration with University of Bern, Switzerland, determined the ability of small hive beetles to transmit pathogens, including viruses and the spore-forming bacterium *Paenibacillus* larvae. The results demonstrated that small hive beetle could be infected with honeybee viruses and American foulbrood spores via food-borne transmission and that this beetle has the potential to act as a mechanical vector for transmission of honey bee pathogens. This research adds additional importance to the control of small hive beetle and predicts the co-occurrence of multiple diseases with heavy small hive beetle loads.

- *Protein supplement is comparable to feeding pollen.* Alternative resources of food are needed by bee colonies when pollen is not available. Protein supplement is comparable to feeding pollen and beekeepers feed protein supplements to colonies during times when flowering plants are unavailable. Whether the supplements are as nutritious as pollen is not known. ARS scientists in Tucson, Arizona, compared the concentration of protein in worker bees as they aged, the development of hypopharyngeal glands, which produce brood food, and immune response among bees fed either pollen or the protein supplement diet (MegaBee) formulated by ARS. The diet generated comparable results to pollen and significantly greater protein concentrations, hypopharyngeal gland development, and immune response than in bees fed only sugar syrup. The supplement is a comparable substitute to pollen and can sustain colony growth and health during intervals when pollen is unavailable.

- *Efficacy of operational device containing brood pheromone in honey bee colonies.* ARS scientists in Weslaco, Texas, conducted a small-scale field experiment to test efficacy of brood pheromone devices (small plastic pouches containing brood pheromone) in overwintering honey bee colonies. Substantial increase of adult and brood population was recorded in all treatments at the end of the study. Growth of the overwintering colonies was very robust. All treatments showed statistically significant improvement in colony strength at the end of the study. Treated colonies performed better in terms of increased number of brood, amount of pollen collected by forages, and increase in consumption of the supplemental diet. Controlled release of the stabilized brood pheromone can potentially enhance colony growth and vigor, improve pollination, and therefore increase crop yield.

- *Honey bee transcriptional response to chalkbrood disease*. Chalkbrood, a major honey bee disease, is widespread, and understanding honey bee immune responses to this disease has become increasingly important. Researchers in Weslaco, Texas, have completed analyses of honey bee genomic response to fungal infection in bees using in vitro larval bioassay and natural mode of infection. Based on genomic sequence analysis, a set of PCR primers were designed to amplify the most promising molecular immune-related targets. These primers are now being evaluated for use in functional studies to examine honey bee immune defenses

against fungal pathogens. This research could lead to a better understanding of honey bee responses to pathogenic fungus, and to improved disease management techniques and improved strength of bee colonies.

- *Successful introduction of DNA into American foulbrood natural plasmids.* ARS scientists in Weslaco, Texas, recently identified several new plasmids in American foulbrood bacteria and created a set of several unique insertions (known DNA sequences) into these natural *Paenibacillus* larvae plasmids. Plasmids are typically circular dsDNA molecules that very often carry antibiotic resistance and/or toxin genes, and are therefore very important in terms of host invasion and resistance to antibiotic drugs. The insertions will allow DNA sequencing of the entire plasmids, which may yield information relevant to the ability of bacterial strains carrying these plasmids to infect honey bee larvae. This is a step toward developing a genetic system for studying the bacterium.

- *Russian honey bees resistant to the small hive beetle.* The small hive beetle is an increasingly serious problem for beekeepers in the southeastern United States. Small colonies used to produce queen bees for sale are especially vulnerable. However, even large healthy colonies can be quickly overrun by beetles after normal beekeeping manipulations. In a comparative study, ARS scientists in Baton Rouge, Louisiana, determined that Russian honey bee colonies harbor fewer adult beetles than did colonies of Italian honey bees. Although this comparative resistance is not sufficient to entirely, together with resistance to varroa, prevent colonies from being devastated by small hive beetles, it is an additional advantage for beekeepers using Russian honey bees. This should result in beekeepers being more vigilant with efforts to control the small hive beetle.

- *Candy board method used for Megabee feeding.* It is necessary to find improved methods for feeding bees when their natural food sources are unavailable. ARS researchers in Tucson, Arizona, tested a new way to feed the MegaBee diet as a candy board, and tested it for palatability and effects on colony growth. The candy board formulation is less expensive to feed to bees compared with the patty formulation, and can stimulate brood production and colony growth to levels comparable to the Megabee patty. The research will impact beekeepers by reducing the cost of supplemental protein feeding while still maintaining colony growth and survival during times of low pollen availability or poor foraging weather.

POLLINATION OF CROPS:

- *High fructose corn syrup effects on honey bees.* Beekeepers feed large amounts of high fructose corn syrup (HFCS) to bees as a sugar supplement. ARS scientists in Tucson, Arizona, conducted studies to identify possible contaminants that might be present in HFCS and the effects on worker honey bee longevity. Worker longevity is a critical component for over-wintering survival, which, when shortened, may precipitate colony collapse disorder. HFCS, when kept at high temperatures in certain types of metal tanks, will form hydroxymethylfurfural (HMF), a substance toxic to bees. Researchers found that HFCS stored in this way and fed to bees could shorten bee longevity and compromise comb building. These results provide beekeepers valuable new information about storing HFCS for optimum use as a bee feed.

NON-*APIS* BEES:

- *Scientists uncover immunity-related genes in alfalfa leafcutting bee.* Honey bees and bumble bees are called "social bees" because they live in colonies and form societies containing a queen and her workers. Bees that do not live in colonies are called "solitary bees" because each female bee is her own queen and she lays eggs in her own nest without workers to help her. Some scientists believe social insects are more vulnerable to disease because of the crowded conditions in which they live. However, little is known about the immune response of solitary bees. ARS scientists at Logan, Utah, and their cooperators conducted the first analysis of immunity-related genes in a solitary bee. The researchers identified 116 immunity-related genes from both healthy and infected larvae of the alfalfa leafcutting bee, a solitary bee that is a major pollinator of alfalfa used to feed livestock. The immunity-related genes found in the alfalfa leafcutting bee are involved in a variety of functions, including cell rescue and cell defense. Similar to the honey bee, the scientists found the alfalfa leafcutting bee to have fewer immune response pathways than have previously been found in other insects. These findings provide a foundation to better understand how bees defend themselves against disease.

- *Alfalfa leafcutting bee use improves with proper stocking density.* The alfalfa leafcutting bee is commonly used to pollinate alfalfa for seed production in the United States and Canada, but these bees frequently have problems with disease, parasites, predators, and unexplained morality of eggs and small larvae. When ARS scientists in Logan, Utah, released bees in field cages at rates typical for use by U.S. alfalfa seed growers, they found there were too many bees, making them less efficient at pollinating flowers and causing them to produce fewer healthy offspring, as compared to when more modest numbers of bees are used. When too many bees are placed in fields, they compete for food and nesting sites, which results in poor bee returns.

- *Blue orchard bees as a supplement to honey bees for almond pollination.* Hands-on practical expertise on blue orchard bee management for almond pollination was developed by ARS scientists in Logan, Utah, and a demonstration project was initiated with extension personnel. Bee reproduction rates in commercial almond orchards was variable during a wet year, although bees in some orchards did increase in number. In a previous year, when weather was better during almond bloom, blue orchard bee populations increased at every site and pollination was successful. Guidance on managing blue orchard bees for almonds is now available for newcomers to the use of this bee**.**

- *Construction of historic range maps for declining bumble bees.* Currently, at least five North American bumble bee species are disappearing, with one species thought to have gone extinct within the last 5 years. Despite the rapid loss of these important pollinators, little is known about the cause of their demise. ARS scientists in Logan, Utah, developed a method for determining the extent and cause of these losses using geographic information systems and historic records of bumble bee collections to create models to predict the geographic range of the bees at different points of time in history. This new method could be used for other pollinators to help scientists understand the effects of climate change or the accidental introduction of pathogens.

- *Fire increases pollinator diversity.* Fires represent major ecological forces shaping forested regions. Controlled burns constitute one method used to manage fuel loads in natural areas. Zion National Park has an active fire management program, but the effects on pollinators remain unknown. Zion National Park is home to 474 different kinds of bees, and these bees are the principal pollinators in forests and shrublands, helping maintain plant diversity. ARS scientists in Logan, Utah, conducted a 2-year study in Zion National Park comparing bee pollinators in adjacent plots of burned and unburned forest and shrubland. In most cases, bee abundance was significantly greater in the burned areas 2 to 5 years after the burn. Burns thus represent opportunities for increasing pollinator populations until forest regeneration.