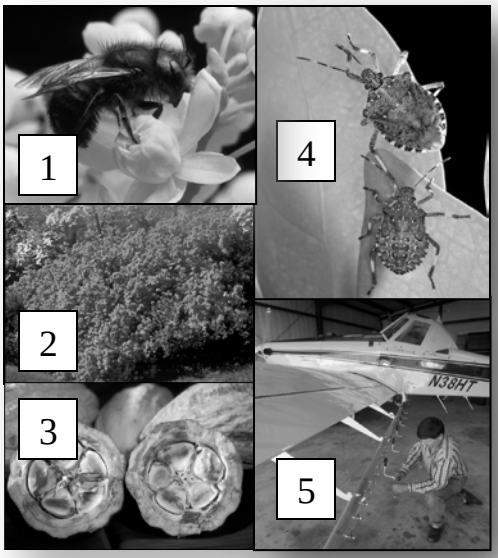
USDA
AGRICULTURAL RESEARCH SERVICE

NATIONAL PROGRAM 305
CROP PRODUCTION

ANNUAL REPORT FY 2011



1. This blueberry bee, *Osmia ribifloris* (on a barberry flower), is an effective pollinator of commercial blueberries and is one of several relatives of the blue orchard bee (*Osmia lignaria*). Similar in appearance, the blue orchard bee is also a successful commercial pollinator that is now being evaluated for use in a wider range of crops including almonds and cherries. Photo by Jack Dykinga.
2. ARS researchers studied hot water dips of azalea stem cuttings, an environmentally friendly control practice for latent web blight, and found it to be a successful component of an integrated disease management strategy to reduce plant damage and routine fungicide use. Photo by Tim McCabe.
3. ARS researchers studied five cacao agroforestry systems in Bahia, Brazil, and their research provided information to help maintain a healthy, diversified soil fauna community, which is a key factor for successful and sustainable cacao production. Photo by Keith Weller.
4. The brown marmorated stink bug (*Halyomorpha halys*), a winged invader from Asia that is eating crops and infesting U.S. homes, is spreading and is expected to continue to do so. Adult (top) and fifth-instar nymph (bottom). Photo by Stephen Ausmus.
5. The efficacy of pest control material is affected by how it is applied. ARS agricultural engineer Clint Hoffmann selects the correct nozzles and locations on the spray boom to deliver the product in large, discrete droplets. Photo by Scott Bauer.

National Program 305
CROP PRODUCTION
FY 2011 Annual Report

Introduction

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

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

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

Production systems must better address the needs of small, intermediate, and large farming enterprises including those using field-, greenhouse-, orchard-, and vineyard-based production platforms, through conventional, organic, or controlled environment strategies. Additionally, adaptation and/or development of technologies are/is 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 a multitude of crops. Colony Collapse Disorder has now increased losses of the honey bee (*Apis*) to a total mortality of over 30 percent. 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 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:

- Component 1: Integrated Sustainable Crop Production Systems
    - 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 2011, grouped by research component. This report is not intended to be a progress report describing all ongoing research, rather an overview that highlights accomplishments, 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 ongoing research programs. If you have any questions, please do not hesitate to contact either of the co-leaders for National Program 305, Kevin Hackett (Kevin.Hackett@ars.usda.gov) or Sally Schneider (Sally.Schneider@ars.usda.gov).

Component 1: Integrated Sustainable Crop Production Systems

SUBCOMPONENT 1A: ANNUAL CROPPING SYSTEMS

Basil polyphenolics influenced by inoculation with mycorrhizal fungi. Nutrient management practices can influence plant production of phenolic compounds and it was unknown whether mycorrhizal fungi have similar effects on these quality components. ARS researchers in Corvallis, Oregon, determined that inoculating basil with arbuscular mycorrhizal fungi increased concentrations of specific polyphenolics. Inoculated basil contains chicoric acid, a putative beneficial component usually found in Echinacea. This research increases knowledge of the sources of phenolic compounds and provides consumers with a potentially more accessible and less expensive source of chicoric acid than Echinacea.

SUBCOMPONENT 1B: PERENNIAL CROPS

Improved technology for producing long-cane blackberry plants. U.S. blackberry growers want to produce blackberries in the off-season. ARS researchers in Kearneysville, West Virginia, used a unique trellis and cane training system to propagate single-cane blackberry plants which can be manipulated to produce off-season fruit that commands a higher price. The new propagation system increased plant output five- to seven-fold over the current commercial propagation technique. The long-cane plants can be established in a warm area, such as southern Florida, in late winter to obtain a crop in March and April. For late season fruit production, plants would be held in cold storage until summer and then grown in a warm environment so that the fruit matures from August to October. This new propagation method is efficient for producing a large number of blackberry plants that can be manipulated to produce fruit in the off-season and would be useful to both growers and nurserymen.

Black raspberry phytochemicals. A large number of black raspberry samples (n=190) were tested for their anthocyanin (natural phytochemical) content. ARS studies uncovered a vast range of pigments existing within a single species. ARS researchers also found new black raspberry mutants that contained a novel anthocyanin profile with rutinoside, as compared to all previous black raspberry anthocyanin profiles that lacked anthocyanins containing rutinosides. This information will provide a valuable baseline for researchers tracking anthocyanin molecular pathways, nutritionists wishing to study the health effects of these compounds, breeders interested in developing new cultivars with improved fruit chemistry traits, and nutraceutical product developers.

Grape tannin evolution. Understanding the kinds and quantities of food quality components naturally present in fruit is critical for selective breeding of better fruit traits to improve U.S. production, fruit product processes, and ultimately the product that reaches the consumer. ARS scientists in Parma, Idaho, carried out a controlled model wine study to examine the evolution of grape skin and seed tannins to assist our understanding of how these compounds change as they oxidize. All monomer and polymer oxidations were dependant on initial solution concentration. As expected, monomer and polymer solutions showed a

decrease in measureable phenolics. Due to the complexity of new structures that are formed, and the limitations of currently available analytical techniques, tannin decomposition by oxidation is difficult to study.

Cover crop residue conserves soil moisture and enhances weed control and grape vine root growth. Cover crops have been shown to improve soil structure and weed control. It was unknown which cover crop practices are best suited for young vineyards in the Pacific Northwest. ARS scientists in Corvallis, Oregon, and collaborators at Oregon State University examined five different vineyard floor management schemes. One included the use of winter cover crop residue grown in alleyways as mulch within vine rows in a young vineyard. The use of the mulch in the vine row increased vine shoot and root growth, suppressed numerous weeds, reduced soil compaction, and maintained higher soils moisture over two growing seasons, as compared to a clean-cultivated control without mulch. The findings suggest that the use of cover crop residues as a mulch can improve vine establishment and conserve soil resources and soil quality when establishing new vineyards in the Pacific Northwest region.

Regulation of flowering in pecan. The plant processes that regulate flowering in pecan have heretofore been a mystery; the relative roles of plant hormones and energy reserves were unknown. ARS researchers in Byron, Georgia, discovered that the development of female flowers is initially regulated by the interplay of at least four classes of hormones within the bud meristem environment during the previous growing season, and is subsequently regulated by non-structural carbohydrate reserves within that same environment the following spring. ARS researchers developed a new theory to explain how flowering in pecan involves a three-phase process acting during the twelve months preceding the visual expression of female flowers. This identifies new research avenues for better understanding the specific physiological processes regulating flowering as well as enabling new opportunities for development of horticultural tools and strategies capable of on-farm regulation of flowering within pecan orchards.

Increasing nut yield with ReTain. Excessive fruit-drop greatly reduces orchard profitability with certain varieties and in certain years. ARS researchers in Byron, Georgia, found that a commercialized natural growth regulator product, AVG (ReTain), reduces premature drop of ‘Desirable’ fruit under field conditions; thus increasing yield in certain years. The research identifies ReTain as a useful horticultural tool for managing crop load on certain sensitive alternate bearing cultivars; thus, providing farmers with a new tool for managing fruit-drop and alternate bearing.

Rare earth elements as likely beneficial micronutrients in pecan. Insufficient understanding of the nutrient element requirements of pecan trees limits productivity and disease resistance. ARS researchers in Byron, Georgia, found that pecan and other hickory species accumulate relatively high concentrations of the rare earth elements; species that possess a duplicate set of chromosomes are especially high accumulators. These elements appear to enable species survival under relatively high stress conditions and appear to be beneficial, or perhaps even essential, nutrient elements that have heretofore been ignored in orchard nutrient management. This information will lead to improved nutrient management of

orchards and will likely contribute to reduced use of fungicides and greater water use efficiency.

Micronutrient nickel to reduce pecan scab in orchards. Pecan scab can cause severe yield loss when environmental conditions are conducive to epidemic development. Furthermore, resistance to certain fungicides used by pecan growers to control pecan scab demands an integrated management approach. Field and in-vitro studies demonstrated a small, but significant, effect of foliar applied nickel at reducing pecan scab. By optimizing nickel nutrition, growers are better managing pecan scab in orchards and are reducing associated crop loss.

*Improving accuracy and precision of pecan scab assessmen*t. Pecan scab causes severe disease on fruit and leaves. Having an accurate, precise, repeatable and reproducible method to assess scab reduces error and improves the quality of data for comparing treatments, and thus ultimately the results on which management decisions are based. ARS scientists in Byron, Georgia, developed a standard area diagram set that aides scab disease assessment on fruit, which reduces error and variability in disease assessments.

Use of phosphite to manage pecan scab in orchards. Pecan scab can result in premature fruit-drop or reduced kernel quality. Emergence of pecan scab resistance to certain classes of fungicides commonly used by pecan growers to control the disease provides a compelling reason to identify novel chemistries with minimal environmental impact to use as alternatives. Field studies by ARS scientists in Byron, Georgia, have confirmed that phosphite is highly efficacious for controlling scab in pecan orchards, and it is now registered for use on pecan. These are the first studies to demonstrate efficacy of phosphite on pecan scab and have resulted in substantial use in commercial pecan orchards.

Cacao genotype influence on soil microfauna. Field studies in Tarapoto, Peru, showed that cacao genotypes had profound effects on population dynamics and species, richness of the rhizosphere microfauna, and increased diversity of microfauna. Such changes in soil microfauna could influence the growth and development of cacao grown in different management systems. Information generated from this research will help cacao farmers select the best cacao genotypes to improve the beneficial microfauna and increase cacao sustainability and yield potentials.

Soil fauna diversity related to soil quality in cacao plantations. A healthy, diversified soil fauna community is a key factor for successful and sustainable cacao production. Cacao is grown in agroforestry systems and shade trees in cacao plantations contribute to a continuous deposition of plant residues. This high soil organic matter content affects the soil quality parameters (physical, chemical, and biological). Changes in soil quality parameters have direct effects on soil fauna diversity and their richness, but little is known about such changes in soils of cacao agroforestry systems. Findings from five cacao agroforestry systems in Bahia, Brazil, showed that acidity, bulk density of soil, and polyphenols and lignin content of tree litter are major factors that control the diversity and richness of soil fauna. Litter management could be a good practice to maintain a healthy soil fauna community and improve the production potential of cacao agroforestry systems.

The information from this research will help cacao growers maintain desirable shade tree species that increase soil fauna activities to improve sustainability of highly productive cacao plantations.

Legume cover crops for improved soil fertility in cacao plantations. Soils of long-term cacao plantations are degraded due to intensive cultivation, non-application of fertilizers, and soil erosion. Research was undertaken in Tarapoto, Peru, to determine the effects of legume cover crops on soil organic matter content and plant-available phosphorous in a cacao agroforestry system. Cover crops improved the soil organic matter content and phosphorous availability. Use of legume cover crops in cacao plantations could improve the soil fertility and reduce soil degradation, helping cacao farmers to improve the sustainability and production of cacao in the highly degraded soils of the Andean region.

Cacao agroforestry system and organic carbon sequestration. In tropical and subtropical regions, organic carbon significantly affects the chemical, physical, and biological properties of soils. Agroforestry systems adapted for cacao cultivations play a major role in the sequestration of carbon because of their higher input of organic materials through litter deposit to the soil. A field experiment in Bahia, Brazil, evaluated variation of organic carbon fractions under cacao agroforestry systems. In cacao agroforestry systems, higher levels of labile organic fractions were observed at surface soil layers indicating that such systems of cacao management play an important role in efficient nutrient cycling and sequestration of carbon.

Impact of location and soil type on yield and fruit quality traits of rambutan cultivars. The globalization of the economy, increased ethnic diversity, and a greater demand for healthy and more diverse food products have opened a window of opportunity for the commercial production and marketing of tropical fruit, including rambutan. There is a lack of formal experimentation to determine yield performance and fruit quality traits of rambutan cultivars. ARS researchers in Mayaguez, Puerto Rico, evaluated eight rambutan cultivars grown on Ultisol and Oxisol soils for 5 years in Corozal and Isabela, Puerto Rico, respectively. Cultivars grown in Corozol had significantly greater number and weight of fruit per hectare than when they were grown in Isabela. Overall, there were no differences amount the eight cultivars in soluble solids concentration except for cultivars Gula Batu and R-156Y, which had significantly lower values at both locations. Cultivar R-162 had higher number and weight of fruit per hectare and high soluble solids concentration at both locations, making it suitable for planting in various agroenvironments particularly on Ultisols typical of the humid tropics. This study provides, for the first time, valuable information to growers and Extension specialists on yield, fruit quality traits and adaptability of rambutan cultivars grown in various agroenvironments.

Natural barriers to fruit fly dispersal in Puerto Rico. Fruit flies are important economic pests of fruits. The presence of a given fruit fly in a region can drastically decrease potential markets for exported fruit or require that the fruit is subjected to potentially harsh and expensive post-harvest treatments. Traps deployed in orchards and adjacent natural areas demonstrated that host availability is extremely important for fruit fly dispersal. The biggest

predictor of number of flies caught in a trap was not its proximity to an orchard, but proximity to a host tree, which are lacking in most natural areas in southern Puerto Rico. All natural areas, including those immediately adjacent to orchards with fruit flies, had low populations of fruit flies and some sites never produced a single fly. Also, collections of fruit from different regions indicated that fruit are consistently differentially infested by region; fruit from some areas consistently yielded more larvae per kilogram of fruit than fruit from other areas. This suggests that natural barriers to fruit fly dispersal exist in Puerto Rico and may be exploited by farms growing fruit susceptible to fruit flies. If extended to an area-wide application, there is potential that the economically important fruit fly species could be eradicated from Puerto Rico entirely allowing growers to expand exports to more markets and do away with post-harvest measures.

Brown Marmorated Stink Bug Working Group. ARS researchers in Kearneysville, West Virginia, initiated formation of the Brown Marmorated Stink Bug (BMSB) Working Group. This group brings together research personnel from USDA, ARS and Land Grant Universities from over 10 states as well as extension personnel, stakeholders, industry representatives, and regulatory officials from the USDA, APHIS and the EPA. This group has formulated research, extension, and regulatory priorities for the BMSB and developed coordinated, collaborative projects aimed at developing effective monitoring and management tools for this invasive species.

SUBCOMPONENT 1C: GREENHOUSE, HIGH TUNNEL, AND NURSERY CROPS

Wheat straw as an alternative to pine bark in container substrates. ARS researchers in Wooster, Ohio, engineered an effective substrate composed primarily of locally produced wheat straw to replace imported pine bark in nursery container substrates. Pine bark is currently used as the primary potting substrate in the nursery industry, but its cost is increasing, its availability is decreasing, and it must be transported over long distances from the southern United States. ARS scientists developed a new potting substrate comprised primarily of wheat straw and low levels of pine bark. On-farm trials have shown that these substrates are effective in a variety of production systems. Adoption of these substrates would reduce dependency on pine bark imported from distant southern states; using instead locally sourced wheat straw biomasses for nursery crop substrates.

New technique for measuring water availability in greenhouse and nursery potting mixes. ARS researchers in Wooster, Ohio, developed a new method to correlate moisture level and plant-available water in nursery and greenhouse potting mixes. Traditional methods for this process were developed for mineral soils. These methods were not precise for porous soils near saturation and thus not useful for greenhouse and nursery potting mixes composed of pine bark, peat moss, and other potting mix components. This new method allows for cost-effective measurement of soil moisture and plant-available water, and can be applied to irrigation models, allowing for more accurate crop irrigation. This will result in more efficient irrigation with less water, nutrient, and pesticide runoff in greenhouse and nursery production.

Mature dairy manure compost substrates for cost savings. ARS scientists in Wooster, Ohio, in collaboration with university colleagues, demonstrated that a water content of 30 percent in the mature dairy manure compost (DMC) substrate provided for wettability equal to the peat moss-perlite substrate at 50 percent water content and a bulk density of 180gram/liter. Benefits of using DMC include pH buffering, supply of pre-plant nutrients that qualify for organic certification, increased cation exchange capacity for greater nutrient retention and reduced leaching, reduction of peat moss consumption, and a substrate component with a cost advantage. The industry norm for substrate formulation is to raise the water content of soilless substrates to 50 percent by weight prior to shipping to ensure a satisfactory level of water absorption for the recipient grower. The increase in weight of the DMC substrate at 30 percent water is only half that of the industry standard substrate at 50 percent water. These results allow for considerable savings in shipping cost which greatly fosters adoption of DMC substrates by the plant production industry.

Nitrogen alters cold hardiness of nursery trees. Stem and bud dieback due to winter injury causes economically important losses in nursery tree production and it is unknown whether plant nitrogen status or the type of fertilizer used influences cold hardiness. Using deciduous bareroot nursery trees, ARS researchers in Corvallis, Oregon, and university collaborators determined that both nitrogen rate and nitrogen form influenced the cold tolerance of buds and stems of nursery trees. Trees with a similar nitrogen status withstand different levels of cold depending on the rate or form of fertilizer used during production. When developing nutrient management strategies for nursery production of trees in climates prone to winter injury, fertilizer component selection is an extremely important factor that growers should consider.

The effect of nitrogen deficiency on geranium growth. ARS researchers in Toledo, Ohio, investigated the threshold beyond which geranium bedding plants cannot normally recover from nitrogen (N) deficiency. Two experiments monitored chlorophyll content and growth of seedlings grown in hydroponic culture in which the N source was removed and then restored after differing lengths of time. Chlorophyll and foliar N levels were shown to rebound quickly after N depravation; however, growth was reduced after just 4 days compared to plants that were provided N constantly. Geraniums grown without N for 4 to 12 days resulted in smaller, more compact plants, with lower shoot to root ratios; these plants did eventually recover. Experiments suggest that geraniums recover from reduced N when grown in hydroponic culture. This information will help growers manage nitrogen inputs.

Hot water dip to control latent web blight in azalea. The pathogen that causes azalea web blight lives on plant tissue all year in the southeastern United States, although it only causes plant damage in July and August. Healthy appearing azalea stem cuttings collected for propagation in May to June may harbor the pathogen, which then multiplies in the propagation house and infests next year's crop. ARS scientists in Poplarville, Mississippi, in collaboration with university colleagues, demonstrated that stem cuttings of twelve diverse azalea cultivars developed normal root systems necessary for successful propagations after submersion in 122°F water for 20 minutes, a treatment that

will kill the fungus that causes web blight. Hot water, an environmentally friendly control practice, is one component of an integrated disease management strategy to significantly reduce both plant damage and routine fungicide usage. The same disease problem occurs on multiple other woody shrub genera, such as holly.

Improved display life of potted tulips. The quality of potted flowers is important to the ornamental industry. ARS scientists in Davis, California, studied the effects of thidiazuron (TDZ) applications on the growth and development of potted tulips 'Christmas Dream.' Plants were treated with foliar sprays of a range of concentrations of TDZ (deionized water, 10µM, 100µM) at two developmental stages - 4 days prior to flower opening (stage one) and the day flowers were just fully-opened (stage two). Spray treatments with 10 to 100 µM TDZ at both stages resulted in a considerable delay in leaf yellowing compared to the untreated controls and TDZ-treated tulip leaves tended to maintain higher chlorophyll contents through the lifecycle. More importantly, treatments with TDZ at 10 and 100 µM at both stages significantly increased the display life of potted tulip flowers, up to 10 days from 6 days in controls. Our results indicate significant potential for TDZ as a tool to improve the postharvest life of potted tulip plants.

Flower senescence – a genetically controlled developmental process. To determine changes in global gene expression during the onset of floral senescence, ARS scientists in Davis, California, developed a Solanaceae micro-array which includes a total of 93,688 expressed sequence tags (EST) from four *Solanum* species (tomato, potato, pepper, and petunia). ARS researchers compared gene expression profiles of petunia petal tissues collected from different developmental stages ranging from 2 days prior to opening to 7 days after opening (right before visible wilting). There were hundreds of up- or down-regulated sequences on day 2 and thousands on day 7. Proteins encoded by genes identified in these studies include many likely candidates for a role in the processes of petal senescence and resource remobilization including protein kinases that might be involved in senescence regulation, cysteine proteases and other enzymes that are associated with protein turnover, nucleases, and proteins associated with cell-walls. Many transcription factors, including representatives of more than 10 different families were up- and/or down-regulated during the onset of senescence, suggesting that a gene network may regulate floral senescence. ARS researchers' studies demonstrate the utility of comparative gene profiling using a cross-species microarray approach for identifying genes with roles in the onset of flower senescence. This knowledge can help researchers develop new varieties or management strategies that lead to longer vase life, i.e., delay of flower senescence.

Controlling flower senescence by inducing expression of a mutant ethylene receptor etr1-1. Ethylene plays very important roles throughout growth and development, including regulation of flower senescence. Plants constitutively expressing the dysfunctional ethylene receptor (etr1-1) to reduce ethylene sensitivity, dramatically extend flower longevity, but show a variety of defects including poor germination, poor root growth, and high susceptibility to disease. ARS scientists in Davis, California, have generated transgenic petunia plants in which etr1-1 is over-expressed in a chemically-inducible system that blocks ethylene perception. The plants develop normally, and the life of the flowers is almost doubled when the plants or excised flowers are exposed to low concentrations of the

inducer chemical (dexamethasone). This approach overcomes most defects associated with constitutively inhibiting the ethylene pathway and provides excellent means for controlling flower senescence.

CROSS –COMPONENT: REMOTE SENSING AND APPLICATION TECHNOLOGIES

Fusion of remotely sensed data enhances field detection of cotton plants. Aerial and ground-based remotely sensed data can be used to detect both different types of vegetation and the vigor/health of this vegetation over large areas. However, new techniques are needed to improve the capability of accurately discriminating between cotton plants and other crop types, given issues with wild/volunteer cotton and cotton pest management programs, such as the ongoing Boll Weevil Eradication Program. ARS researchers in College Station, Texas, acquired airborne and ground-based spectral reflectance data over three large agricultural fields in central Texas. Accurate discrimination between cotton plants and other crop types was achieved by analyzing independent aerial and ground-based datasets and combined datasets, using a multi-sensor data fusion technique. Crop type classification accuracy of remotely sensed data acquired by the aerial and ground-based sensors was approximately 90 percent, but improved to greater than 99 percent by using the data fusion technique. This research has achieved great accuracy and reliability in detection of growing cotton, and will be of major benefit in supporting the Boll Weevil Eradication Program by detecting plants that harbor weevils that would otherwise go unnoticed and untreated.

Early detection of the onset of crop stress for effective crop production management. Hyperspectral imaging provides a technique for great potential for early detection of crop injury. A visible near infrared hyperspectral imaging system was successfully employed by ARS researchers in Stoneville, Mississippi, in collaboration with Geosystems Research Institute of Mississippi State University, to determine herbicide-induced crop response to glyphosate applied at different application rates. Use of this system will allow the determination of the specific spectral bands that indicate onset of crop stress due to herbicide induced damage, nutrient deficiency, and water deficiency.

High speed wind tunnel supports aerial application industry. Modern aerial application aircraft make spray applications at speeds up to 220 MPH, which exceeds the capability of current wind tunnels used to develop spray models. ARS researchers in College Station, Texas, developed a new high-speed wind tunnel testing facility capable of generating airspeeds in excess of 220 MPH, and developed and implemented testing protocols for the new wind tunnel. This facility has already been utilized to extend the airspeed range of the ARS spray atomization models, including the first-ever documented atomization data for U.S. Air Force C-130 aircraft spray application at airspeeds exceeding 200 MPH. These new high-speed models are critical in helping aerial applicators make effective spray applications that meet regulatory requirements and that are in full compliance with agrochemical product use labels.

Crop spraying guidelines to prevent off-target movement of spray. Aerial applicators should not spray during unfavorable atmospheric conditions, which include atmospheric temperature inversions and stable atmosphere, to prevent crop damage and environmental hazards caused by long distance off-target movement of spray. ARS researchers documented the times of the day and weather conditions in the mid-south United States and found that spraying should not occur when wind speed was less than about 3 mph and when there was less than a 3to 4°F temperature rise from the morning low. An important finding was that the time window during which spraying was permissible was shortened by about 2 hours under cooler weather conditions. This research will help growers maximize the benefit of pesticide applications while minimizing the environmental impact.

Droplet evaporation and spread on waxy and hairy leaves. Pesticide spray application efficiency is often improved with enhanced droplet adhesion on leaf target surfaces, which is achieved by the addition of adjuvants to spray mixtures. Effective pest control with reduced pesticide use can be achieved if the active ingredients in droplets spread out uniformly and remain on the target area. ARS researchers in Wooster, Ohio, and The Ohio State University researchers determined the fate of water droplets amended with different classes of adjuvants at various concentrations on plant leaves. The researchers clearly demonstrated that the use of adjuvants could greatly improve the homogeneity of sprayed pesticides to increase the coverage area on waxy and hairy leaves, thereby offering possibilities of reduced pesticide usage and providing economic benefit to the farmer and reduced risk of environmental contamination. Growers, extension educators, and chemical companies in the United States and other countries are using the research findings to increase pesticide application efficiency.

Comprehensive application technology and strategy to reduce pesticide use. Pesticide applications are critical to ensure healthy, unblemished ornamental nursery plants. Conventional spray application practices recommend the modification of carrier volume for preparations of spray mixtures, but not the amount of active ingredients per unit area. ARS researchers in Wooster, Ohio, demonstrated that growers could use their existing spray equipment to reduce pesticide and water use by 50 percent by properly changing spray nozzles at no extra cost and still achieve effective pest and disease control. This equates to doubling the pesticide application efficiency while reducing pesticide costs, reducing health risk to applicators, and diminishing adverse impact to the environment. Other benefits accrued with this approach included increased operational efficiency (the area sprayed is doubled thus the frequency and travel time required for the tank refilling times are reduced) and reduced costs for energy consumption and new equipment, as well as reduced risk of pesticide exposure of workers. By using the half-rate practice, growers reported savings of over $200-$500 per acre.

Optimal spray application rates for ornamental nursery liner production. Production of liners is an essential process for providing abundant bareroot stocks for the ornamental nursery industry. Liners are one to 3-year old young trees grown in nurseries prior to being transplanted to fields or containers where they continue growing into larger, market-ready shade trees. They are normally planted densely and grow rapidly during a growing season,

which can aggravate the severity and incidence of insect infestations and diseases. In response to an onset of pest infestations and diseases, spray applicators must make decisions within a very narrow time frame on how much pesticide and spray volume is needed for economical control. ARS researchers in Wooster, Ohio quantified the amount of spray deposition and coverage inside ornamental nursery liner canopies from an over-the-row frame vertical boom sprayer, determined its optimal application rates, and established a spray rate model for different size liners. Growers are now using the research findings to increase spray application efficiency, minimize potential environmental contamination due to over application of pesticides, maximize the effectiveness of pest management strategies, and achieve real cost savings for liner production in the ornamental nursery industry.

Variable-rate sprayer for nursery liner applications. Growing liners is a specialized business for some ornamental nurseries. Liners are young trees grown in densely planted rows for 2 to 3 years, and then sold to other nurseries that transplant and grow them to market size. Because of their rapid growth in a confined space, pesticide applications are needed to protect them from insect pests and diseases. However, variations in tree size and varieties invariably confound spray applications and over-applications of pesticide are possible. ARS researchers in Wooster, Ohio, developed an experimental intelligent sprayer using ultrasonic sensors and pulse-width modulated spray nozzles to deliver real-time variable-rate sprays to liners based on their canopy size. The newly developed sprayer can achieve uniform spray deposition and coverage for nursery liner applications despite variations in liner canopy size and sprayer travel speed; thus contributing to more uniform pest control.

Mechanized delivery of herbicide to potted nursery plants for improved weed control. ARS researchers in Wooster, Ohio, identified means for assessing herbicide deposition on potted plant leaf surfaces, evaluated the effectiveness of irrigation water for moving granular herbicides down through a leaf canopy onto the substrate surface, and evaluated the uniformity of granular herbicide distribution from an air-assisted, granular spreader. Irrigation is commonly recommended to move herbicide granules off a canopy following an application. A unique collection system was devised for collecting granular and liquid herbicides as well as for measuring the amount of irrigation water collected under the canopy of a potted plant. ARS research found that this practice provides minimal measureable change in the amount of herbicide on the surface of the potted plant substrate. A granular applicator developed originally for golf course lawn treatments was successfully adapted to deliver granular herbicides through canopies at different stages of development at higher rates of speed than traditional hand-held applications. ARS scientists are working with Ohio State staff to demonstrate the application of air-assist, broadcast, granule spreaders and transfer these research findings to the nursery industry to increase the efficiency of their weed control programs.

Insecticide movement through plants with implications for insect control. ARS Researchers in Wooster, Ohio, initiated greenhouse studies to understand pathways of systemic pesticide movement in plants and how insecticide delivery could influence biological efficacy. ARS scientists have previously documented how difficult it is to apply insecticides uniformly around plant canopies from traditional spray devices. Trials included delivery of a systemic

insecticide to two different parts of the plant: application of high volume drench to the potted root zone of plants or application to a single leaf in the middle of the plant canopy. Evaluation of chemical residue in leaf tissue and mortality of green peach aphids caged on select leaves at five different elevations on the target plants demonstrated that the drench treatment to the plant roots produced more uniform chemical movement and aphid mortality along the plant profile than a foliar application. Technology transfer opportunities are being used to demonstrate to floral producers how to implement these findings into their pest management programs to improve the success of systemic insecticide application programs, which will in turn reduce chemical expenses and produce higher quality floral products.

Improved techniques/protocols for spray applications in pest control. Effective control of mosquitoes and other insects that vector human diseases requires precise spray application techniques. New technologies are needed to efficiently monitor the dispersal of very small droplets over large sampling areas and to evaluate the efficacy of insecticide treatments using caged insects in the field. ARS researchers in College Station, Texas, established the collection efficiency of two commonly used rotary slide spray samplers under multiple wind speeds and spray droplet sizes and developed correction factors that estimate actual spray droplet size and aerial concentration. The research also established the impact of insect bioassay cages on airspeed, spray droplet size, and spray concentration inside the cages, and developed correction factors that estimate actual spray concentration presented to caged mosquitoes. The sampling techniques and protocols developed by this research provide major advancements in the predictive value of laboratory and field test data that guide real world spray application for control of major pest and disease-transmitting arthropods.

Component 2: Bees and Pollination

SUBCOMPONENT 2A: HONEY BEES [*APIS*]

New product that controls bee mites with acids from hops. *Varroa* mite is the most important pest of honey bee colonies and causes major colony losses due to parasitism and transmitting viruses, many of which are associated with Colony Collapse Disorder. Beekeepers need new methods to control *Varroa* mites because currently registered products are either inconsistent in their effectiveness, harmful to brood, contaminate wax combs, or no longer control *Varroa* mites because the mite is resistant. Under a Cooperative Research and Development Agreement, ARS scientists in Tucson, Arizona, developed a product (commercialized as Hopguard™ by BetaTec Hop Products) that uses beta plant acids from hops to reduce varroa mite populations in colonies. A Section-18 emergency registration was issued by EPA and HopGuard™ is now in commercial production and being used in honey bee colonies.

Controlling the key parasite of honey bees, Varroa destructor, through genomics. Novel controls based on genomics will provide for strong control of the parasitic mites of honey bees, *Varroa destructor*, while reducing the use of chemicals. A draft genome sequence was published for this mite, revealing potential weak points in its biology (defensive proteins and proteins used in chemical mitigation) and candidates for novel controls such as RNA interference (RNAi), a method for knocking down specific pest proteins. The description of mite candidate genes allowed the worldwide initiation of RNAi-based control efforts for this parasite; with the first successful demonstration of RNAi activity in *Varroa* in late 2010.

Research on bee feed demonstrates effects on bee health. Beekeepers feed high fructose corn syrup or sucrose to colonies as a carbohydrate source when flowering plants are not available; protein is fed when pollen is scarce. ARS scientists in Tucson, Arizona, demonstrated that colonies fed during the winter with sugar syrup made with sucrose had greater brood production in the spring compared with colonies fed high fructose corn syrup. A high rate of brood production in the spring is important for building strong colonies for the pollination of early season crops such as almonds. Similarly, ARS scientists in Baton Rouge, Louisiana, found that continual feeding of protein and sugar syrup and feeding protein enriched with pollen in mid-winter produces colonies that far exceed the sizes needed for almond pollination. This effect is enhanced if beekeepers use eight-frame equipment.

Tools developed for tracking and understanding Colony Collapse Disorder. Efforts to improve bee health have suffered from an inability to accurately assess disease caused by viruses and other pathogens. ARS scientists in Beltsville, Maryland, have improved methods for collecting honey bees from representative populations, shipping them for genetic analyses, stabilizing and extracting RNA, conducting high-throughput genetic screens for viruses and other pests, collecting embryos from established colonies, and carrying out controlled experiments on adult bees. These methods are being used in national surveys in the United States in order to establish cell lines and other genetic techniques and to better determine interactive effects.

Genes associated with Nosema infection determined by microarrays. In 2010, researchers in Weslaco, Texas, verified the infection status of bees infected with *Nosema* using DNA and microarray approaches. Microarray analyses revealed that, as expected, *Nosema* infection alters bee biological processes regulating nutrition and behavioral maturation, but surprisingly infection does not appear to significantly alter immune gene expression in midgut and fat body tissues up to 7 days post-infection. ARS scientists will continue to examine impacts of infection by characterizing gene expression in immune-related tissues up to 2 weeks post-infection in bees infected with *Nosema*. These studies identify host response to *Nosema* infection and will lead to downstream applications in commercial management, improving the strength of the honey bee colonies.

Honey bee responses to fungal diseases. Using a genome-wide approach, ARS researchers in Weslaco, Texas, identified a large set of genes in the honey bee fungal pathogen *Ascosphaera apis*. Data analysis revealed key components responsible for pathogen reproduction and host invasion. A wide variety of molecules found in this study are well-known target sites of the anti-fungal drugs currently used in treatments of animal diseases, and thus can be tested against *A. apis*, the chalkbrood fungus. Results of this study, in combination with ARS researchers' previous data, support the theory that activation of disease defenses in the honey bee negatively affects most of the bees' biological functions, including the nutritional status and response to pesticide poisoning. This research will lead to development of new management strategies in support of healthy bee colonies.

Russian honey bee genes predominant in a feral population of honey bees. Because of the ravages of *Varroa destructor* feral populations of honey bees have almost disappeared. Feral honey bees are major pollinators of many plants in a variety of ecosystems so their loss has led to a critical shortage of naturally occurring pollinators. ARS scientists in Baton Rouge, Louisiana, have determined that a feral population of honey bees has developed near Russian apiaries which have *Varroa* resistant honey bees and that it is predominantly Russian in parentage. This observation suggests that feral populations of honey bees will rebound in areas that have beekeepers that use *Varroa* resistant stock.

SUBCOMPONENT 2B:NON-*APIS* BEES

Stressing bees can make them more resistant to disease. The reasons behind bee declines has been a major concern for beekeepers and researchers, and many hypothesize that the declines are a result of increased susceptibility to disease due to increased stress. However, ARS researchers in Logan, Utah, found that when the alfalfa leafcutting bee was exposed to a temperature stress, either being excessively chilled or overheated, that chalkbrood infections actually declined; activity of the immune system increased, and this activity reduced the ability of the pathogen to infect the bee. These results help us to understand the relationship between stress and disease, assisting beekeepers in maintaining healthier hives.

Blue orchard bees keep their homes nearby. Blue orchard bees can be very effective pollinators for almonds, but the best methods for releasing them on large farms has been uncertain. Blue orchard bees readily nest in plastic boxes hung from almond trees. ARS scientists in Logan, Utah, found that many evenly distributed small nest boxes hung

throughout the orchard resulted in more bees nesting than fewer, larger boxes. More nests mean more bees for the next year and that more flowers are being pollinated, increasing nut yields.

Ground-nesting bees can survive the heat of range fires. Vast wildfires sweep over millions of acres of wild rangelands in the United States annually, altering vegetation, but the impacts on pollinators was unknown; most bees in these rangelands nest underground. Heat tolerance experiments conducted by ARS scientists in Logan, Utah, demonstrated that these bees, of all ages, are not killed until soil temperatures exceeded 120 degrees. However, only the top two inches of soil reached these temperatures in a fire, and 91 percent of the bees were found to nest deeper than two inches. Bees are critical to the success of restoration projects after wildfires, and this experiment demonstrated why native bees return so quickly to burned areas, even when all the plants have been destroyed.