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BEFORE THE
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AGRICULTURE COMMITTEE
SUBCOMMITTEE ON HORTICULTURE AND ORGANIC AGRICULTURE

OVERSIGHT HEARING—COLONY COLLAPSE DISORDER
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Mr. Chairman, Ranking Member Neugebauer, and Members of the Subcommittee, I am Dr. Caird Rexroad, Associate Administrator of the Agricultural Research Service (ARS). I am here today speaking on behalf of both ARS and the Cooperative State Research, Education, and Extension Service (CSREES), both of the Research, Education and Economics (REE) mission area of the United States Department of Agriculture (USDA). ARS is the primary intramural science research agency of USDA, operating a network of over 100 research laboratories across the nation on all aspects of agricultural science. CSREES is the primary extramural research agency of USDA and the Federal partner for the Cooperative Extension System. CSREES maintains wide ranging partnerships with over 130 colleges of agriculture, 59 agricultural experiment stations, and 57 cooperative extension services.

Thank you for the opportunity to appear before the Subcommittee today to present testimony about USDA efforts to address the problem of colony collapse disorder, known as CCD. This disorder, which has no recognizable underlying cause, is characterized by the sudden disappearance of a bee colony's population, with only a few bees remaining near the deserted hive. These outbreaks of unexplained colony collapse pose a threat to the pollination industry, the production of commercial honey, and production of at least 30% of our Nation's crops.

Mr. Chairman, in light of the significance of this threat, I am pleased to share with you USDA's current research efforts to investigate the cause of CCD. I will provide you with a brief overview of the disorder as well as a summary of our research and outreach efforts addressing the problem.

OVERVIEW OF COLONY COLLAPSE DISORDER

Beginning in October of 2006, beekeepers became alarmed that honey bee colonies were dying across the continental United States. Beekeepers reported unexplained losses of 30 to 90 percent, and the phenomenon typically involves the sudden loss of all but a few bees from a colony's populations, with only a laying queen and a small cluster of attendants remaining. After further investigation, researchers determined that outbreaks of CCD have probably been occurring for at least two to three years.

CCD poses a problem for many segments of the agricultural community, particularly the pollination industry and the many growers that depend on pollinating services. In total, bee pollination is responsible for $15 billion in added crop value, particularly for specialty crops such as almonds and other nuts, berries, fruits, and vegetables. The California almond crop alone requires 1.3 million colonies of bees, a need that is projected to grow significantly by 2010. Due to CCD, the bee industry is facing great difficulty meeting the demand of almond producers. If researchers are unable to solve the problem, and beekeepers are unable to meet demand for this and other crops, agriculture will be significantly impacted.

This could, indeed, be the perfect storm for pollination services. With invasive pests and diseases of bees increasing over the last two decades, we may have now reached a tipping point where the bee colony can no longer fight back. To make matters worse, this is occurring just as pollination needs, particularly for almonds, are increasing.

USDA RESEARCH ADDRESSING CCD

ARS and CSREES are both conducting and funding independent and collaborative research to determine what is causing the sudden disappearance of bee colonies. Presently, ARS is collaborating with Pennsylvania State University, the University of Illinois, North Carolina State University, the University of Montana, and the Pennsylvania and Florida Departments of Agriculture. These institutions have formed a Colony Collapse Disorder (CCD) Working Group. In conjunction with the ARS Customer Workshop on Bees, the CCD Working Group met with the bee industry and scientists on February 19, 2007, in Stuart, Florida, and developed a plan for determining the cause of colony collapse.

Immunosuppression and Bee Stress

Beekeepers experiencing CCD indicate that their colonies were under some form of stress at least two months before the first incident. Bees live in colonies, in societies, and depend on those societies to protect them. Unlike other insects that have greater ability to detoxify pesticides and resist pathogens, bees rely on their ability to rid the hive of sick bees or adjust temperature in order to control diseases. Stress can hinder this ability significantly, ruining the normal function of the bee colony. Eventually, stress can compromise bees' immune systems and leave them susceptible to disease, just as it can do to humans.

The CCD Working Group has sampled affected colonies at various locations and shared field research, and researchers found that there were a large number of disease-causing organisms present, particularly agents causing "stress-related" diseases (*Nosema*, European foulbrood, and others). Researchers therefore believe that, due to the magnitude of infectious agents being detected in adult bees, the immune systems of bees are becoming suppressed. This immunosuppression could be occurring for a number of reasons, and scientists suspect that some form of stress or combination of stresses, such as pathogens, limited or contaminated water supplies, pesticide application, the ordeal of being moved long distances during migratory beekeeping, or inadequate nutrition, may be working together to suppress the immune systems of bees and contributing to CCD.

ARS has a number of projects in place to improve the immune responses of bees and increase disease resistance. Work includes a genomics-based program in Beltsville, Maryland, and

Weslaco, Texas, to determine bee immunity and resistance to pathogens such as the American foulbrood bacterium and chalkbrood fungus. The results of this work will be incorporated into bee breeding work in Baton Rouge, Louisiana, where researchers have been working to develop a bee with increased resistance to the varroa mite and tracheal mite.

Next, I will discuss what we consider the top four causes of stress on bees, and what ARS is doing to counter these problems.

Varroa Mite

The number one suspect is the varroa mite, which invaded the United States in the 1980s, and has been linked to serious colony decline for the past few years. It is possible that by directly feeding on bee brood, varroa mites are playing a major role in CCD. Unfortunately, the mite has become resistant to many miticides. Now, the ARS Beltsville lab has found out that the mite not only kills bees by feeding on them, but also transmits pathogenic bee viruses. Therefore, the mite is almost certainly contributing to increased stress on bees.

During the past few years, USDA has put considerable energy into finding solutions to the varroa crisis, and progress has been made. The Beltsville lab has developed a screen insert that keeps mites from crawling back onto bees once they have dropped to the bottom of the hive; the Gainesville lab is in the process of developing a trap; and the Tucson lab has found a chemical, produced by the bees themselves and incorporated into beeswax, that kills the mites; this chemical is being developed into a control method. The Weslaco lab is developing other alternative miticides.

ARS researchers in Baton Rouge are conducting genetic research to locate resistance genes and breed bees with increased resistance to mites. Two lines of bees, the Russian bee and the SMR-trait bee, have already been found to have considerable resistance to the mite. With the completion of the bee genome sequencing project, ARS scientists are applying this achievement to improve honey bee breeding even further. Researchers will attempt to use marker-assisted breeding as one genome-based technique to breed a more resistant bee. Although marker-assisted breeding is not likely to replace field breeding, this method can be used to screen stock for specific traits, such as varroa mite resistance, prior to field-testing.

Work funded by CSREES through the National Research Initiative (NRI) is addressing suppression of varroa mite reproduction. There are a number of ongoing research projects at Land Grant Universities that are funded through the Hatch formula allocations to State Agricultural Experiment Station scientists. These projects include Integrated Pest Management (IPM) projects to establish treatment thresholds for the varroa mite; evaluate control methods for varroa, including genetic and cultural methods; and restore mite-resistant feral honey bee populations.

Pathogens

Another group of possible CCD-related stressors are various pathogens, such as viruses, spiroplasmas (bacteria without cell walls that are often parasitic in plants and arthropods), fungi, and others, that may be either killing bees directly or compromising their immune systems. *Nosema ceranae*, a microsporidian that causes diarrhea in bees, is suspected to be a possible cause of CCD, because it was believed to have entered the Nation recently and coincided with the onset of CCD. Spain, another nation that has recently been affected by bee decline, reported that *Nosema* has risen in incidence from 10 to 90 percent from 2000 to 2004.

ARS scientists in Beltsville, Maryland, have recently probed our collection of bees at Beltsville and have evidence that this microbe has been in our country since at least 1995; therefore, we think it is less likely to be a cause of the recent CCD outbreak here. Also, colonies that die of Nosema normally contain some dead bees, an occurrence that has not been seen with CCD. Nevertheless, we need to investigate this organism to make sure that it is not causing the current crisis, particularly since Nosema infected bees have been shown to take cleansing flights – to rid their guts of the microbe – in temperatures as low as 4 degrees Celsius, which is cold enough to kill bees.

A second group of pathogens – bee viruses – can cause brain pathologies in bees and therefore might contribute to the immunosuppression suspected in CCD. At present, bees can be affected by at least 20 viruses, and scientists have probes for only a few. Organisms that infect the bee brain might cause brain damage that would make it hard for the bees to communicate the location of food or water sources by their dance language, or to find their way back to the hive after foraging.

For our next steps regarding our top two pathogen suspects, we need to determine how long Nosema has been in this country, and we need to develop better probes for viruses. Other unanswered questions include the role of the varroa mite in transmitting viruses and the seriousness of viral diseases in bees. Upon discovering these answers, we need to perform tests to see if we can replicate CCD using any of these suspected causes. And, if we identify a cause, we need to counter it – perhaps using fumigants for Nosema, or resistance breeding for viruses.

Regarding other pathogens, parasites, and depredators that could be contributing to CCD, ARS researchers at various locations will continue to research the tracheal mite, the small hive beetle, spiroplasmas, and fungi such as *Aspergillus*, to determine if these factors are contributors to CCD and to develop control methods for them to reduce overall bee stress.

In addition, Weslaco scientists are using the recently sequenced honey bee genome to investigate bee immunity to chalkbrood disease, caused by another fungus. To date, researchers at the lab have used the bee genome to find genes for Toll receptors that give immune cells the ability to produce chemicals to respond to and kill microbes. This work will help improve bees' defenses against a number of microbial pathogens.

Beltsville scientists are also studying bee immune responses and disease resistance, having recently discovered that it is possible to trigger bee immunity to the American foulbrood bacterium by feeding bee larvae a non-pathogenic bacterium. Researchers at this location have also identified a genetic screen that can be used to look for resistance.

A recent CSREES-NRI grant has funded ARS scientists to study genomic approaches to disease resistance in honey bees. Aspects of Hatch-funded research at Land Grant Universities include investigations on the control of the small hive beetle and on genetic and cultural methods to control Nosema apis disease. University scientists are also investigating mechanisms of disease virulence, transmission, and epidemiology of honey bees.

Migratory Stress

Migratory stress is another stressor that may contribute to CCD; migration has increased due to increased demands on beekeepers for colonies for almond pollination, resulting in bee crowding and lack of hygiene, as well as forced mixing of old foragers and young nurse bees, which can spread disease. It is common for 10 percent of colonies to die after transportation, with losses of 30 percent possible after the pollination of some crops.

During the migration process, colonies can also become stressed due to splitting – the dividing of a colony into one or more new colonies. Older bees that are forced to act as nurse bees may be less effective at provisioning, and may carry increased pathogen loads. In addition, the use of contaminated equipment or old comb during splitting could expose bees to increased levels of pathogens or pesticides accumulating in comb wax.

ARS has recently begun investigating the effects of migratory stress. In 2005, the ARS location in Weslaco began to study whether and how hive movement affects the health of bees.

Pesticides

Finally, many pesticides are toxic to bees. Based on findings from the bee genome, it has become apparent that bees have very weak detoxifying systems for breaking down pesticides. Applications of pesticides such as the miticide coumaphos (used for controlling the varroa mite) can accumulate in hive wax, reducing worker longevity, and killing queens reared in that wax. In addition, even if not lethal to bees, some pesticides may increase the stress levels of bees, making colonies more susceptible to disease. And the neonicotinoid insecticide imidacloprid has been shown to impair neurological function in bees. If so, foraging bees, which rely on memory to locate food and water and find their way back to the hive, might be particularly vulnerable.

We hypothesize, therefore, that factors that stress bees or impair bee brain function may be linked to bee disappearance in CCD.

ARS and our university partners plan to expand on these findings to study the effect of pesticides on bee brains, and to test the effects of pesticides on bees in the apiary. ARS is now participating with the CCD Working Group to organize a program that will further investigate the effects of pesticide exposure on bees under field conditions. We need field studies to determine if pesticides in this category are harming bees in the field, not only during acute exposure, but also at sublethal dose levels. Are they disrupting bee learning or the colony's social harmony?

ARS Areawide Integrated Pest Management (IPM) Project and Bee Nutrition and Health

While we continue to look for the cause of CCD, ARS also intends to test current technologies in an attempt to produce healthy bees, no matter what stress they are under. This will be done through our Areawide Integrated Pest Management (IPM) Project, a project to investigate almonds in California and other crops elsewhere, which will focus on migratory beekeeping. This bee project, which would study varroa management, would also address other bee parasites, diseases, and predators such as the small hive beetle, which feeds on hive stores of honey and pollen. Significantly, however, it focuses on bee health by improving their nutrition, as we have achieved through the development of supplemental diets at Tucson. Poor nutrition, due to overcrowding of bee colonies, pollination of crops with low nutritional value, or lack of pollen or nectar, has been associated with poor bee health and is a suspected contributor to CCD. Even well-provisioned colonies may be weak coming out of the winter, so we have sugars and pollen substitutes that help them increase their numbers before bloom. This is particularly important for pollination of almonds, which bloom early in the season.

In 2006, we tested the Areawide concept for bee health and showed that the winter feeding of protein is beneficial to bees, but that colonies already in a weakened state before winter do not grow sufficiently to meet pollination standards for almonds. The entire Areawide Project will incorporate additional studies that simulate poor nutritional conditions for bees in the summer and fall and incorporate corrective management practices.

CSREES-NRI has funded key research on the impact of plastic combs on recruitment, communication, and honey production, as well as on the commercial development of a synthetic pheromone to increase foraging and pollination efficiency. A new multi-state research project supported by CSREES will collaborate with the CCD Working Group to address CCD and other apiary problems.

OUTREACH AND EXTENSION
ARS conducts outreach to key stakeholders through workshops such as the Customer Workshop on Bees and through regularly scheduled programmatic review processes that involve diverse stakeholder groups. CSREES provides significant funding for extension programs related to beekeeping, pollinators, and honey production. Currently, extension entomologists with responsibilities for apiculture are active in 21 states. These programs are funded in part by formula-based allocations through the Smith-Lever Act, in addition to state and county-based funding.

FUTURE RESEARCH AND OUTREACH PLANS
To date, research indicates that there are a few common factors shared by beekeepers experiencing CCD, but no common environmental agents or chemicals standing out as causative. In an effort to solve this problem, ARS will work to continue and expand its research to address this problem. In the future, the Agency will involve researchers from all ARS laboratories in the CCD Working Group. ARS will also be coordinating the development of a 5-year Strategic Plan with the Cooperative State Research, Education, and Extension Service, university researchers, the bee industry, and growers, to develop and implement research projects to investigate and solve the problem.

In particular, researchers will be capitalizing on the recently released honey bee genome to investigate those areas listed above and many others related to bee health. Both ARS' intramural and CSREES' extramural programs have been instrumental in supporting this accomplishment. The use of this genomic information will have great applications in improving honey bee breeding and management. As an initial step, university researchers are preparing to submit a proposal to the CSREES Critical and Emerging Pests and Diseases Program to use microarray hybridization assays to identify genes associated with CCD. Samples of bees from healthy and declining colonies have already been collected through the auspices of the CCD Working Group and the American Beekeeping Federation.

Mr. Chairman, ARS and CSREES, in collaboration with other USDA agencies and private institutions, conduct and fund much ongoing research that addresses the paradigm surrounding CCD. We will continue to work to improve bee health and prevent colony collapse. These efforts will be critical in checking CCD as it causes damages to beekeepers, the pollination industry, and agricultural producers across the United States.

The USDA REE mission area, through both ARS and CSREES, is pleased to conduct and fund research and provide leadership in this effort to solve the mystery of colony collapse disorder. We thank you for the opportunity to share our research with you. Mr. Chairman, this concludes my remarks. I would be pleased to answer any questions at this time.