**The Situation:** Since its discovery in California in 2008 in San Diego and Imperial Counties, Asian citrus psyllid (ACP) was declared the worst pest ever to threaten California grown citrus. The reason for this concern is due to the ability of this sucking bug to spread a bacterium that causes a lethal and incurable citrus disease, Huanglongbing (HLB). In April 2012, the industry’s gravest fear was realized was HLB was found in Hacienda Heights in Los Angeles County. ACP is now common in many urban areas in southern California and Los Angeles County appears to be ground zero for very large and widespread populations. These Los Angeles populations are much more severe and widespread than those that have been contained in San Diego and Imperial Counties, and may represent an introduction of ACP independent of those that invaded close to the California-Mexico border. These urban LA populations (and growing urban populations in Riverside and San Bernardino Counties) represent two threats to commercial citrus producers: (1) high ACP densities present a migration threat out of backyards towards major production zones in Ventura County, the Central Valley and the Coachella Valley. ACP in these infested areas also have the potential to move into San Diego and Orange Counties. (2) Lots of ACP in urban citrus means there are lots of opportunities for feeding adults and nymphs to pick up the HLB-causing bacterium from diseased trees and spread it to healthy trees. This type of acquisition followed by tree to tree transmission of bacteria by infected ACP can rapidly amplify the occurrence and distribution of HLB in California.

**The Response to the ACP-HLB Problem:** The University of California Riverside (UCR), the Citrus Research Board (CRB), the California Department of Food and Agriculture (CDFA), and the California Citrus Pest and Disease Prevention Committee (CCPDPC) have combined forces to combat ACP infestations in urban areas. The primary method of control spearheaded by the citrus industry and CDFA has relied exclusively on pesticide applications to citrus in residential gardens. Applications have consisted of quick acting foliar sprays to knock down ACP nymphs and adults followed with systemic insecticides applied to the soil which provide slower acting but more persistent protection against ACP. Visual surveys of trees expressing symptoms suspiciously similar to HLB and molecular testing of ACP adults and suspect plant material are being conducted to identify HLB infected citrus. While the pesticide application program has been successful in killing ACP on infested citrus, this approach is expensive. Some figures suggest that it probably cost about $11 million to treat about 68,000 properties in Los Angeles, and this may represent only about 3% of properties with citrus in this area. Consequently, the Los Angeles spray program was abandoned and efforts were redirected to the outer edge of ACP invasion in February 2012. This outer edge, referred to as the CDFA “Blue Line” is likely to be expanded outwards again as ACP populations are detected more frequently outside of the area under active treatment. A more cost effective approach would be to re-direct this program and set up “defensible” space around commercial production areas and treat these “buffer” zones to slow incursion by ACP.

**The Biocontrol Option:** Suppression of ACP in Los Angeles County has not been abandoned entirely, and the control program has entered a new phase, one that is now relying on mercenaries recruited from Pakistan. The biological control program in Los Angeles is utilizing a parasitoid called *Tamarixia radiata*, which was collected by Mark and Christina Hoddle (Entomologists with the University of California Riverside) from the Punjab of Pakistan. The Punjab was selected for foreign exploration efforts for several reasons. First, the prevailing climate is about 70% similar to the Central Valley, and climate matching is thought to be important when searching for natural enemies; you want to find biological control agents that are...
well adapted to the climate in the area in which you intend to release them. Second, the first research on ACP and its associated natural enemies on citrus was conducted in the Punjab and published in 1927, suggesting this may be part of the area where ACP evolved. Third, Dr. Iqrar Khan, the Vice Chancellor of the University of Agriculture in Faisalabad (UAF), the cooperating institute in Pakistan, was a MS and Ph.D. graduate from UC Riverside whose area of expertise is citrus diseases with an emphasis on HLB!!! VC Khan and colleagues from Agri-Entomology at UAF have been enthusiastic supporters of this project. From September 2010 to June 2012, five trips were made to Pakistan and UAF was the base camp for foreign exploration to collect parasitoids of ACP. Collections were made at different times and in different locations in an attempt to find as many natural enemy species as possible and to capture a broad genetic snapshot of parasitoid populations attacking ACP. It is thought that high levels of genetic diversity will provide an excellent opportunity for natural selection to weed out weak genetic strains while promoting proliferation of strains best adapted to California’s varied climatic zones. The collecting trips found two species of parasitoid attacking the nymphs of ACP, Tamarixia radiata and Diaphorencyrtus aligarhensis. Colonies of both parasitoids are in the Quarantine and Insectary Facility at UC Riverside.

Safety Testing and Releases: Before parasitoids could be released in California, they had to be tested to determine if they posed undue risk to non-target species in California. It took Dr. Raju Pandey, a post-graduate researcher at UC Riverside, about 18 months to complete the safety testing for Tamarixia in Quarantine. The results of safety-testing experiments were used to prepare a 60 page Environment Assessment Report for USDA-APHIS to review. This report was submitted in November 2011, and in mid-December 2011, approval was granted to release Tamarixia from Quarantine for liberation in southern California. On December 20, 2011, the first releases of Tamarixia were made at the biocontrol grove on the UC Riverside Campus. Subsequent releases have been made in the cities of Azusa, Bell Gardens, Chino, Duarte, Fontana, Los Angeles, Mira Loma, Montclair, Ontario, Pico Rivera, Pomona, Rialto, Riverside, San Bernardino and Whittier. By August 2012, about 10,000 parasitoids have been released at about 50 different sites.

In June 2012, the first evidence of Tamarixia attacking ACP in southern California was detected at about four release sites, and at two sites, there was evidence that Tamarixia had spread 20-65 meters on its own to attack ACP on infested plants on which releases had not been made. The evidence for attacks on ACP by Tamarixia came from the discovery of ACP husks or mummies that had circular exit holes in them. The presence of these holes indicated that Tamarixia adults had emerged from these dead ACP. Prior to releasing Tamarixia in California, examination of thousands of ACP had failed to detect any evidence of parasitism. This lack of natural enemy activity may have allowed ACP populations to grow and spread rapidly.
Collections of parasitized ACP and adult Tamarixia from these sites were made so their DNA could be analyzed and compared to DNA from the Pakistani Tamarixia in colonies at UC Riverside. The preliminary results from the DNA analyses conducted by Dr. Paul Rugman-Jones, a Research Associate in Dr. Richard Stouthamer’s lab at UC Riverside, suggested strongly that the parasitoids were likely of Pakistani origin. Further, molecular tests suggest that there is very high genetic diversity in the populations that are establishing in California. We think that these preliminary results are very positive because releases of Tamarixia began during winter and relatively few parasitoids (about 10,000) have been released at a modest number of sites (about 50). Despite this, field observations are tentatively suggesting that establishment and spread of Tamarixia may be occurring in some areas and genetic diversity is high.

One thing we have noticed in the field is that Argentine ants actively guard ACP on citrus and they will attack and kill Tamarixia if they find them. It appears that the ACP reward the ants with honeydew, a sugary waste product, and we have seen ants carrying ACP nymphs to new places to feed. Ant control in some areas may be very important for establishing this parasitoid. This is a great example of one invasive pest (the ant) facilitating another invasive pest (ACP).

**Future Plans:** The biocontrol program is now entering a very ambitious phase. With funding from the Citrus Research Board and cooperation between teams at the CDFA (headed by Dr. David Morgan) and UC Riverside (a research team comprised of Dr. Richard Stouthamer, Dr. Joseph Morse, Dr. Anna Soper, and Mark Hoddle) the medium-term plan is to greatly boost production of Tamarixia at UC Riverside so greater numbers of parasitoids can be released at more sites. Mass production is being supervised at UCR by Lisa Forster (UCR), and releases and monitoring of Tamarixia establishment and spread are being done by Christina Hoddle (UCR), Anna Soper (UCR), Ruth Amrich (UCR), and Grace Raderbaugh (CDFA). Dr. Raju Pandey (UCR) is conducting studies evaluating the efficacy of organic pesticides to kill ACP and assessing their compatibility with Tamarixia. This data may help develop IPM programs for organic growers enabling them to use organically-registered pesticides with carefully timed releases of Tamarixia for ACP suppression. Dr. Pandey is also conducting in Quarantine the safety evaluations for Diaphorencyrtus, the second ACP parasitoid from Pakistan. This parasitoid may be cleared for release from Quarantine in late 2013 once the EAR has been approved by USDA-APHIS.

**Conclusions:** The ACP biocontrol program is not a silver bullet for ACP-HLB management. Rather it is one tool that will be part of an emerging and complex control program that will need to simultaneously manage ACP and HLB, and other resident pests and diseases in commercial citrus. At this time, Pakistani natural enemies are the best option available for suppressing ACP populations in urban areas where spray programs have been abandoned. These mercenaries have the ability to cross unseen over locked gates and fences, dodge pitbulls, and bypass uncooperative homeowners to find ACP infested citrus. They also work for free 24/7/365! For more information on this program along with regular updates please visit the Center for Invasive Species Research blog: http://cisr.ucr.edu/blog/