Biological Control of the Asian Citrus Psyllid Shows Promise in Southern California's Residential Landscapes

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The Problem

Asian citrus psyllid (ACP), *Diaphorina citri* (Hemiptera: Liviidae) was first discovered in southern California in 2008. This invasive pest is widespread and flourishing in countless unmanaged residential citrus trees throughout San Diego, Imperial, Riverside, Los Angeles (LA), Orange and San Bernardino counties. These urban orchards provide a safe haven where ACP populations can thrive in absence of insecticides. If uncontrolled, ACP of urban origin may spill over into neighboring commercial citrus groves. This immigration threatens commercial citrus because ACP can transmit the bacterium responsible for huanglongbing (HLB), from infected urban trees. HLB was first detected in Florida in 2005, and is now widespread throughout that state. In turn, ACP-HLB has reduced Florida's citrus production to its lowest output rate since the 1960s, a catastrophic economic loss (Hall et al. 2012). In 2012, HLB was detected in Los Angeles County, but the disease has not yet gained a foothold in California's commercial groves. Therefore, it is crucial that California PCAs, growers, and homeowners work together to keep ACP and HLB out of commercial citrus.

Figure 1. (A) *Tamarixia radiata*, a tiny parasitic wasp that attacks 4th to 5th instar Asian citrus psyllid nymphs, is currently being released across Southern CA in an effort to control ACP-HLB. **(B)** Asian citrus psyllid colony comprised primarily of 4th and 5th instars. Photos by Mike Lewis.

Recruiting Foreign Mercenaries to Fight ACP in Urban Areas

In commercial citrus groves threatened by ACP, pesticides are the recommended ACP-HLB control strategy. Conversely, biological control of ACP is being employed in urban residences where regular insecticide applications are not feasible. In 2011, scientists from UC-Riverside began releasing *Tamarixia radiata*, a host-specific parasitoid of ACP sourced from Punjab Pakistan, with the intent of suppressing urban ACP populations across southern CA (Figure 1). As of January 2015, the California Department of Food and Agriculture (CDFA) have released ~1,100,000 parasitoids. This parasitoid has established multiple stable populations in urban areas, some organic orchards, and it has even spread to sites where it was never released (Hoddle and Hoddle 2013). Despite these release efforts, the efficacy of *Tamarixia* in controlling urban ACP population growth and spread remains largely unknown. To address this shortcoming, we have been monitoring urban ACP populations for over three years. In this article, we discuss preliminary results of biweekly ACP and *Tamarixia* phenology survey data across 11 sites over a 2 to 3.5 year period in Riverside and LA Counties.

Conducting ACP and *Tamarixia* Surveys on Backyard Citrus

Urban sites for monitoring ACP and natural enemy activity were selected based on UCR and CDFA *Tamarixia* release data. Bi-weekly monitoring of ACP and *Tamarixia* has

Table 1. Site summary of bi-weekly ACP population survey sites.					
Site name	**Start date**	**County**	**City**	**Trees**	***Tamarixia* status**
Penn Mar	6/29/2011	Los Angeles	South El Monte	1 lemon, 1 lime	Invaded*
Maplefield	7/12/2011	Los Angeles	South El Monte	1 lemon	Released**
Poinsettia	1/25/2012	Los Angeles	El Monte	1 lemon	Invaded
Strozier	1/25/2012	Los Angeles	South El Monte	1 lemon	Invaded
Badillo	1/25/2012	Los Angeles	Baldwin Park	1 lemon	Invaded
Rodeway Inn	8/22/2012	Los Angeles	Azusa	2 curry	Released
Asuza	9/28/2012	Los Angeles	Azusa	2 orange, 2 lemon	Released
Lochmoor	11/1/2012	Riverside	Riverside	2 lemon, 2 orange, 2 grapefruit	Released
Jurupa	11/20/2012	Riverside	Mira Loma	2 lemon, 2 lime, 1 orange, 1 grapefruit	Released
Indiana	1/6/2013	Riverside	Riverside	6 orange	Invaded
60th PL	1/23/2013	Los Angeles	Maywood	1 lemon	Invaded

*Invaded indicates that *Tamarixia* colonized this study site without deliberate human assistance.

**Released indicates that *Tamarixia* was deliberately released at the study site as part of the ACP biocontrol program.

been ongoing for a maximum of 3.5 years at 11 sites and 31 trees (Table 1). For each sampling event the following data are collected:

(1) Adult ACP Density Estimates: Timed two-minute visual counts are made for adult ACP in four quadrants of each experimental tree for a total of eight minutes per tree (Figure 2).

(2) Host Plant Phenology: ACP population growth is limited by flush growth since adult females only oviposit on this young plant material and ACP nymphs develop almost exclusively on flush growth. Therefore, leaf growth is visually characterized in each quadrant using a standardized area, a metal hoop (172 cm^2). Flush growth consists of three age-sequential stages, all of which are characterized by soft light green tissue. In contrast, non-flush growth consists of stiff mature leaves that are dark green in coloration.

(3) Densities of Immature ACP and Parasitism Rates: From each quadrant, a single flush twig is removed (four twig samples per tree) and then transported

Figure 2. Field technicians conducting two-minute visual ACP adult counts at a Los Angeles residence. Photo by Ruth Amrich.

under CDFA permit to the UC-R Insectary & Quarantine facility for processing. Under a desiccating microscope, the number of ACP eggs, nymphs (categorized in two groups (I) small, 1st-3rd instars, and (II) large, 4th-5th instars), and parasitized nymphs (determined via dissection) per cm of flush are recorded.

Results to Date

Preliminary results from 11 residential sites across Los Angeles and Riverside County are encouraging. *Tamarixia* appears to have established in many areas; it is spreading, and likely regulating ACP numbers which may help reduce urban population densities. For instance, at one site in LA County, ACP adults exhibited a **6-fold decrease** in peak densities since *Tamarixia* establishment (Figure 3). However, the efficacy of *Tamarixia* is highly variable with peak parasitism rates being less than 15% at some sites. We suspect that the Argentine ant, another invasive pest, may be hindering biocontrol efforts in southern California's urban landscape. These ants are abundant at most survey sites and have been observed to protect ACP colonies from their enemies (including *Tamarixia*: Figure 4). In exchange, colonies of ACP nymphs provide ants with honeydew, a sugary waste product that nymphs excrete (Tena et al. 2013).

In southern California, ACP densities vary across sites and citrus variety, and these trends are strongly influenced by time of year, suggesting that there is predictable seasonality to ACP phenology. For example, peak ACP densities occur in the fall and spring. Host tree flushing patterns appear to be

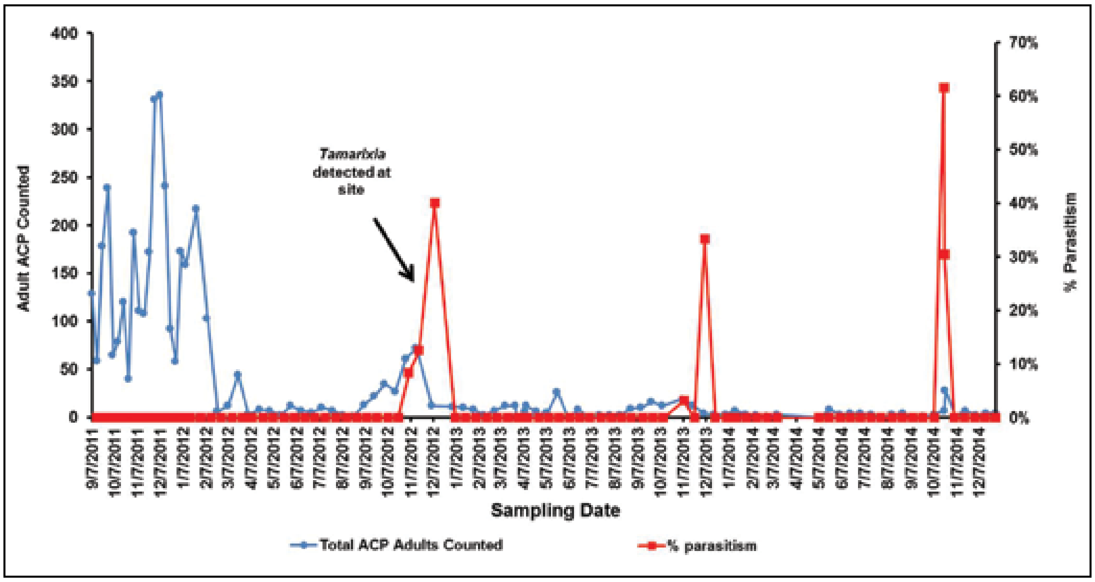

Figure 3. Phenology of ACP and percentage (%) parasitism of ACP nymphs by *Tamarixia* on limes at a site in Los Angeles.

Figure 4. Argentine ant attacking the parasitic wasp, *Tamarixia*, as it attempts to parasitize ACP nymphs. Photo by Mike Lewis.

Dry Conditions Demand New Pest Control Strategies for Almond Crops

Industry experts share advice for optimal pest-control strategies while water remains limited.

Amid California's parched landscape, irrigated orchards are attractive oases for insect pests, making pest control an even more critical component of almond crop production this year. The University of California's Frank Zalom, Ph.D., professor of entomology, and Franz Niederholzer, Ph.D., farm adviser, offer recommendations to help pest control advisers (PCAs) support customers as they navigate unprecedented growing conditions.

Demonstrate Support

Experts are calling this the worst drought in decades and help from experienced PCAs will be key to achieving the best possible outcomes. "Growers are facing unfamiliar challenges and will rely heavily on their PCAs for guidance and support," says Niederholzer.

He recommends maintaining a strong presence in growers' orchards. "Don't wait for standard scouting and treatment times. Make regular visits, walk the orchards and report on what you see. Your presence can provide growers with peace of mind and demonstrate your interest in the long-term success of their operations."

"Growers are facing unfamiliar challenges and will rely heavily on their PCAs for guidance and support."

Stay Alert

As heat units accumulate, pests such as navel orangeworm (NOW), which do not diapause, could emerge earlier than normal. "Pay attention to the biology of the pest, not the calendar," says Niederholzer. "Check pheromone and NOW egg traps regularly and watch for anything that looks suspicious. The more information you gather, the more accurately you can time spray applications later in the season."

Optimize Foliar Applications

With potential for income-limiting water levels, growers will be cost-conscious when it comes to making foliar applications, says Zalom. One way to boost efficiency while protecting crops from insect damage is to take advantage of May sprays to target both NOW and peach twig borer (PTB).

An effective option that suits that strategy is DuPont™ Altacor® insect control. Flexible application timing, long-lasting residual control and an excellent environmental profile make it an ideal fit for the spring period.

"May sprays were a practice we avoided with broad-spectrum insecticides because of concern over disrupting natural insect predators and mites," says Zalom. "But now that we have products like Altacor® that are not as disruptive to beneficials and offer residual control, growers can take advantage of May sprays and likely control PTB and resident NOW populations with one application."

Niederholzer cautions that drought-stressed trees may "harden off" earlier than in more normal years and could respond unexpectedly to foliar applications. He recommends careful planning ahead of spray applications. "Most of us have never worked in orchards under such extreme drought conditions. It makes sense to take every precaution to protect crops this year."

For more information on protecting almond crops from pest damage, visit cropprotection.dupont.com and ipm.ucdavis.edu. ■

Flexible Pest Control Maximizes Yield Potential

Lasting, effective control and an excellent environmental profile make DuPont™ Altacor® insect control a valuable option for protecting almond crops. Key benefits include:

- Exceptional control of lepidopteran pests, including navel orangeworm and peach twig borer
- Flexible application timing
- Short four-hour re-entry interval
- Minimal impact on beneficials
- Excellent spray-tank stability under a wide range of pH levels

the most important factor driving ACP population dynamics across sites. Common ACP host plants found in residential Californian gardens include oranges, lemons, limes, grapefruit, and curry (a close relative of citrus). We found that lime and curry trees flush more frequently than other host plants. Consequently, over time, these trees exhibit the largest populations of ACP adults, nymphs, and eggs and natural enemy populations. Likewise, researchers in Florida found that the frequent flushing of ornamental orange jasmine yielded the highest ACP populations in residential landscapes compared to other ACP host plants (Tsai et al. 2002).

Recommendations for Managing ACP in Urban Areas

Due to the heterogeneity of southern California's residential landscape, management of ACP and HLB is complex and multifaceted. Consequently, educating California homeowners will be crucial to the successful suppression of urban ACP population growth and spread. Here are some urban management suggestions that we think are important for optimizing ACP biological control in urban areas:

1) Residential sites with large numbers of fast flushing lime and curry trees will likely support more ACP than other types of citrus. In the absence of pesticides, these plants may act as "insectaries" for producing ACP natural enemies like *Tamarixia*. Natural enemies would disperse from these "nursery" plants to neighboring properties, including commercial citrus orchards, and assist with ACP biocontrol.
2) Argentine ant management may help facilitate suppression of urban ACP numbers by enabling both naturally occurring predators (e.g. lady beetles and lacewings) and *Tamarixia* easy access to ACP colonies. Deployment of bait stations for reducing ant foraging activity in trees could be extremely important for ACP biocontrol.
3) Differences in garden care among private residences, such as hedging (which promotes flush growth), watering and fertilization, pest management, and flora diversity, may either hinder or enhance urban ACP population growth and have strong influences on natural enemy impacts. For example, residences where land owners frequently hedge their citrus trees may promote flush growth needed for young ACP to flourish which in turn can be exploited by *Tamarixia* and other natural enemies (e.g., lacewing larvae). On the other hand, urban gardens with an abundance of flowering plants can promote predatory hover fly (Syrphidae) populations because adult flies obtain nectar from flowers. In turn, ACP nymphs provide food for syrphid larvae which are voracious ACP predators.

Future Work

To better understand natural enemy activity on ACP in urban areas, life table studies are under way. These studies track cohorts or families of ACP on small citrus trees from egg all the way to adulthood. A major strength of life table studies is the determination of factors responsible for life stage specific mortality (e.g., parasitism by *Tamarixia* or predation by syrphid fly larvae). Another aspect of this work is to determine *Tamarixia* establishment in southern California release sites as well as migration into areas where it has not been released. Taken together, these studies will help us better understand the impact *Tamarixia* is having on ACP populations in urban areas.

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