Asian Citrus Psyllid

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The Asian citrus psyllid, *Diaphorina citri* Kuwayama (Homoptera: Psyllidae) is a pest of citrus and close relatives of citrus (fig. 1). Asian citrus psyllid damages plants directly through its feeding activities. New shoot growth that is heavily infested by psyllids does not expand and develop normally and is more susceptible to breaking off. There is greater concern, however, over the fact that the psyllid is an efficient vector of the bacterium that causes the economically devastating disease called citrus greening or "Huanglongbing".

Figure 1. Asian citrus psyllid

Asian citrus psyllid is found in tropical and subtropical Asia, Afghanistan, Saudi Arabia, Reunion, Mauritius, parts of South and Central America, Mexico, and the Caribbean (fig. 2). In the United States, Asian citrus psyllid was first found in Palm Beach County, Florida, in June 1998 in backyard plantings of *Murraya paniculata* (orange jasmine) (fig. 3). By 2001, it had spread to 31 counties in Florida with much of the spread due to movement of infested nursery plants (Halbert et al. 2002). In the spring of 2001, Asian citrus psyllid was accidentally introduced into the Rio Grande Valley of Texas on potted nursery stock (orange jasmine) from Florida (French et al. 2001). The Asian citrus psyllid could invade California at any time, with most likely sources of infestation being Florida, Mexico or Asia. There were 170 interceptions of Asian citrus psyllid at USA ports on plant material (primarily *Murraya* and citrus) from Asia during 1985-2003. Citrus greening disease is not yet found in the United States, but it is found throughout Asia, the Indian subcontinent and neighboring islands, the Saudi Arabian peninsula, and in the Saõ Paulo State of Brazil. The citrus greening pathogen is transmitted by psyllid vectors, grafting, and possibly by citrus seed. A disease-free citrus budwood program combined with detection and eradication of Asian citrus psyllid are essential components of the program that protects the California citrus industry from citrus greening disease.

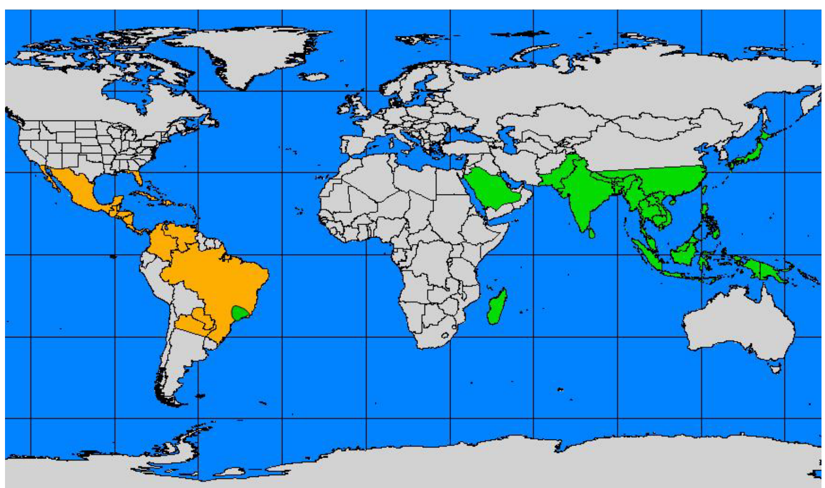

Fig 2. Worldwide distribution of Asian citrus psyllid (orange) and Asian greening disease + the psyllid (green)

Host Plants

The host range of Asian citrus psyllid includes 25 genera in the family Rutaceae, although not all of these are good hosts (Halbert and Manjunath 2004). The most common or preferred hosts are in the genera *Citropsis, Citrus* (fig. 4), and *Murraya* (fig. 3). Because of its restricted host range, monitoring efforts for this pest should be focused on citrus and closely related plants.

Figure 4. A mandarin variety of citrus tree

Figure 3. *Murraya paniculata*, orange jasmine

Psyllid Life Cycle

Adults. Psyllids are small insects, 3-4 mm in length (fig. 5). Adult Asian citrus psyllids are brownish and usually feed on the underside of leaves. They feed with their heads down almost touching the surface of the leaf and, because of the shape of their head, their bodies are lifted at about a 45° angle (fig. 6). The adults will jump or fly a short distance when disturbed (Mead 1977). Adults can live for 1-2 months at temperature below 68^{o}F (Lieu and Tsai 2000). The adult female abdomen turns bright yellow-orange when she becomes gravid.

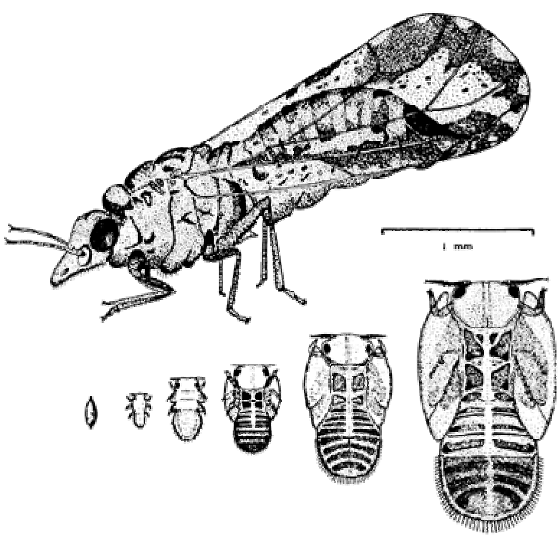

Figure 5. Life cycle of Asian citrus psyllid

Figure 6. Psyllid adult feeding

Figure 7. Brightly colored psyllid eggs and adult

Eggs. Asian citrus psyllid females lay their bright yellow-orange, almond-shaped eggs on the tips of growing shoots or in the crevices of unfolded "feather flush" leaves (fig. 7 and 8). The number of eggs laid is dependent upon host plant. For example, a mean of 857 eggs per female were deposited on grapefruit, whereas a mean of 572 eggs per female were deposited on rough lemon. At 77°F, the eggs hatch in about 4 days (Tsai and Liu 2000).

Nymphs. Asian citrus psyllid nymphs (0.25 – 1.7 mm in length) are generally yellowish-orange in color and feed exclusively on new growth (fig. 9). The nymphs move in a slow, steady manner and/or flick their abdomens upwards when disturbed. There are five nymphal stages (5 instars) that look similar, but increase in size after each molt (fig. 5). The later instars have large wing pads. The feeding nymphs produce waxy tubules that direct the honeydew away from their bodies (fig. 10). Nymphal survival rates vary with citrus variety.

Figure 8. Psyllid eggs and hatching nymphs

Figure 9. 5th instar psyllid nymph

Figure 10. Waxy tubules produced by nymphs

Development from Egg to Adult requires 16-17 days at 77° F, and, under uniformly warm conditions with suitable flush continuously present, the psyllid could complete up to 30 generations per year. Survivorship of adult Asian citrus psyllid is best at humidities above 53%, however, there is significant survival at humidities as low as 7% (McFarland and Hoy 2001). Asian citrus psyllid does not diapause, but decreases in density when citrus is not flushing because the immature stages require flushing plant material. Asian citrus psyllid were present year-round in southern Florida on orange jasmine, a common ornamental shrub (Tsai et al. 2002). Densities of the psyllid peaked in May, August, and October through December in southern Florida. This coincided with new flush growth in the orange jasmine. This plant is thought to serve as an alternate host for Asian citrus psyllid when citrus is not in flush because of its more continuous flushing pattern.

Direct Damage Caused to Citrus by Asian Citrus Psyllid Feeding.

Asian citrus psyllid directly damages citrus and closely related ornamentals (Halbert and Manjunath 2004). Psyllids extract large quantities of sap from the plant as they feed and produce copious amounts of honeydew. The honeydew coats the leaves of the tree and sooty mold growth results (fig. 11).

Figure 11. Sooty mold growing on the

In addition, as Asian citrus psyllid feeds, it injects a salivary toxin that stops terminal elongation and causes the malformation of leaves and shoots (fig. 12) (Michaud 2004). A single psyllid nymph feeding for less than 24 hours on a citrus leaf causes permanent malformation of that leaf. Overwintering adults will aggregate on newly forming citrus leaf buds where they feed and mate. Oftentimes, initial infestations of Asian citrus psyllids are highly aggregated on individual trees within citrus orchards. This aggregation and feeding results in some distortion of the leaf buds that provides improved oviposition sites. Citrus flush is often severely damaged (fig. 13 and 14), resulting in the abscission of the leaf and shoot (Halbert and Manjunath 2004) or malformed leaves (fig. 15). Mature trees can can tolerate this damage since the loss of leaves or shoots is only a small portion of the total tree canopy. Nursery trees and new plantings may require chemical protection.

Figure 12. Twisted tips of new citrus flush due to psyllid feeding

Figure 13. Burnt tip of citrus foliage due to psyllid feeding

Figure 15. Distorted citrus leaves due to previous psyllid feeding

Figure 14. Malformed citrus leaves due to psyllid feeding

Asian Citrus Psyllid as a Vector of the Bacterium that Causes Citrus Greening Disease

The most serious damage caused by Asian citrus psyllid is due to its ability to efficiently vector the phloem-inhabiting bacteria, *Candidatus* Liberibacter asiaticus that causes citrus greening disease (Huanglongbing). In the past, this bacterium has been extremely hard to detect and characterize. In recent years, however, DNA probes, electron microscopy, and ELISA tests have been developed that have improved detection (Roistacher 1991, Garnier and Bove 1993, Bove et al. 1996).

Figure 16. Chlorosis of citrus leaves due to L. asiaticus

Symptoms of citrus greening include yellow shoots and mottling and chlorosis of the leaves (fig. 16) (Capoor et al. 1974). The mottling superficially resembles zinc deficiency. However, the mottling associated with citrus greening disease does not just run along the veins as in Zinc deficiency, but will cross leaf veins. Infected trees are stunted, sparsely foliated, and may bloom off-season (fig. 17). In addition, there is twig dieback, leaf and fruit drop, production of small, lopsided, hard fruit, and small, dark aborted seeds (fig. 18). The juice of the infected fruit has a bitter taste. Fruit do not color properly, leading to the name greening. This disease is one of the most devastating of graft and insect transmitted pathogens of citrus in the world. In parts of Asia, it has substantially reduced the

Figure 17. Stunted, sparsely foliated trees with citrus greening disease

Citrus greening disease can be found throughout the warmer areas of Asia, India, and the Saudi Arabian Peninsula. In July 2004, citrus greening disease was reported in Brazil where it was found to be affecting large areas of Saõ Paulo State (fig. 2). Antibiotics injected into infected citrus trees provide only temporary remission of symptoms. The host range of citrus greening is limited to citrus and some closely related relatives of citrus. While *Murraya* hosts the psyllid vector, it is not a good host of the disease.

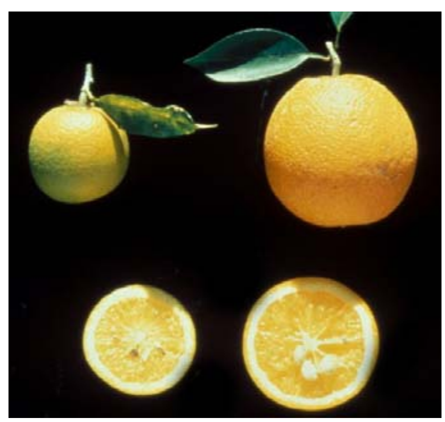

Figure 18. Small, hard fruit that do not color properly (left) compared to uninfected fruit (right)

Monitoring for Asian Psyllid in California.

Monitoring should be conducted by visually inspecting the **new flush** of citrus (fig. 19) and ornamental nursery plants such as orange jasmine (*M. paniculata*) that potentially act as hosts of Asian citrus psyllid. Monitoring should include a search for **all insect stages** including the gray to brownish adults (fig. 20) and the brightly colored yellow-orange eggs and nymphs (fig. 21). Adults jump easily and should be collected with an aspirator. Eggs and small nymphs are difficult to see without a hand lens. Nymphs flatten themselves around the shoot and eggs are tucked inside crevices and leaf folds. Special attention should be given to **damage** caused by Asian citrus psyllid including twisted and curling shoot tips, sooty mold, and white waxy deposits on the leaves (fig. 22 and 23). Yellow or green **sticky cards** can be used as a method for detecting adult psyllids (fig. 24).

Figure 19. Twisted tips of citrus foliage

Figure 20. The characteristic body tilt of the adult citrus psyllid

Figure 21. Psyllid eggs and nymphs tucked into crevices and folds

Figure 22. Honeydew, sooty mold, and waxy tubes

Figure 23. Heavy infestation of psyllids on *Murraya*

A positive find should be verified, then treated appropriately to reduce the chance of survival and spread of the infestation. The extent of the infestation should be delineated using visual surveys and the appropriate regulatory actions taken to minimize the spread of Asian citrus psyllid from the site. Regulatory steps may include infested plant destruction, insecticidal treatment of plants around the infestation, quarantine of the area, and additional surveys of the area during periods of new flush.

Figure 24. Yellow sticky card for psyllid detection

Long-term Management of Asian Citrus Psyllid in Florida. Asian citrus psyllid is now established throughout Florida and integrated pest management (IPM) practices have been developed to help reduce the damage that it causes to citrus. If the pest were to become established in California, similar tactics would be utilized.

Chemical control. While biological control is an important component of the Florida Asian citrus psyllid control program, chemical control is likely to be the primary control method used during eradication efforts in California. In Florida, the flush tissue of young trees in nurseries and new plantings are protected from psyllids by applying Admire (imidacloprid) as a systemic insecticide. Generally, only nurseries and new plantings are treated because mature citrus trees can withstand the physical injury caused by the psyllid. Uptake of Admire is a function of tree size and soil type. Smaller trees or seedlings will take up Admire more rapidly than larger trees. Because the action of Admire is fairly slow, this treatment should be combined with a foliar treatment of a neonicotinoid such as Provado (imidacloprid) or a pyrethroid such as Danitol (fenpropthrin) for more immediate control. Horticulutral mineral oil also has some limited efficacy.

Biological control. Populations of Asian citrus psyllid in Florida are fed upon by many generalist arthropod predators such as spiders, lacewings, hover flies or syrphids, minute pirate bugs and attacked by a number of parasites. (Michaud 2004).

Coccinellid Predatory Beetles. Two lady beetles, *Olla v-nigrum* (Mulsant) and *Harmonia axyridis* Pallas (fig. 25), are the most important predators of Asian citrus psyllid nymphal populations in Florida. On some terminals, all Asian citrus psyllid nymphs are eaten by immature and adult stages of these lady beetles.

Fig. 25. Coccinellid predatory beetle

Hymenopterous Parasites. Two tiny, wasp parasites of Asian citrus psyllid nymphs have been imported, investigated for safety to the environment, and released in Florida. The parasite *Tamarixia radiata* (Waterston) (fig. 26) was imported from Taiwan and Vietnam, and the parasite *Diaphorencyrtus aligarhensis* (Shaffee et al.) was imported from Taiwan. Both parasites were released in Florida with apparently only *T. radiata* establishing (McFarland and Hoy 2001). The wasp lays its eggs underneath the psyllid nymph where the larva feeds on and kills its host. The parasite emerges as an adult from underneath the dead psyllid or through a hole that it chews in the body of the psyllid (fig. 27).

Fig. 26. Parasitic wasp *Tamarixia radiata*

Fig. 27. Exit hole in a dead psyllid, indicating parasitism

Literature Cited

Bove, J. M., N. M. Chau, H. M. Trung, J. Bourdeaut, and M. Garnier. 1996. Huanglongbing (greening) in Viet Nam: Detection of *Liberobacter asiaticum* by DNA-hybridization with probe In2.6 and PCR-amplification of 16S ribosomal DNA. pp. 258-266 *In* J. Da Graca, P. Moreno, and R. K. Yokomi, eds. Proc. 13th Conf. Internatl. Org. Citrus Virol. University of California.

Capoor, S. P., D. G. Rao, and S. M. Viswanath. 1974. Greening disease of citrus in the Deccan Trap Country and its relationship with the vector, *Diaphornia citri,* Kuwayama. pp. 43-49 *In* L. G. Weathers and M. Cohen, eds. Proc. 6th Conf. Internatl. Org. Citrus Virol. University of California.

Catling, H. D. 1970. Distribution of the psyllid vectors of citrus greening disease with notes on the biology and bionomics of *Diaphorina citri*. Food Agric. Organ. Plant Prot. Bull. 18: 8-15.

French, J. V., C. J. Kahlke, and J. V. da Graca. 2001. First record of the Asian citrus psylla, *Diaphorina citri* Kuwayama (Homoptera: Psyllidae) in Texas. Subtrop. Plant Sci. 53: 14-15.

Garnier, M. and J. M. Bove. 1993. Citrus greening disease. pp. 212-219 *In* P. Moreno, J. V.da Graca, and L. W. Timmer (eds.) Proc 12th Conf. Internatl. Org. Citrus Virol. University of California, Riverside.

Halbert, S. E. and K. L. Manjunath. 2004. Asian citrus psyllids (Sternorrhyncha: Psyllidae) and greening disease of citrus: A literature review and assessment of risk in Florida. Florida Entomol. 87: 330-353.

Halbert, S. E., C. L. Niblett, K. L. Manjunath, R. F. Lee, and L. G. Brown. 2002. Establishment of two new vectors of citrus pathogens in Florida. Proc. International Soc. Citriculture IX Congress, ASHS Press, Alexandria, VA. pp. 1016-1017.

Liu, Y. H., and J. H. Tsai. 2000. Effects of temperature on biology and life table parameters of the Asian citrus psyllid, *Diaphorina citri* Kuwayama (Homoptera: Psyllidae). Annals Appl. Biol. 137: 201-216.

McFarland, C. D. and M. A. Hoy. 2001. Survival of *Diaphorina citri* (Homoptera: Psyllidae), and its two parasitoids, *Tamarixia radiata* (Hymenoptera: Eulophidae) and *Diaphorencyrtus aligarhensis* (Hymenoptera: Encyrtidae) under different relative humidities and temperature regimes. Florida Entomol. 84: 227-233.

Mead, F. W. 1977. The Asiatic citrus psyllid, *Diaphorina citri* Kuwayama (Homoptera: Psyllidae). Florida Dept. Agric. Cons. Serv., Div. Plant Industry Entomology Circular No. 180. 4 pp.

Michaud, J. P. 2004. Natural mortality of Asian citrus psyllid (Homoptera: Psyllidae) in Central Florida. Biol. Control 29: 260-269.

Roistacher, C. N. 1991. Techniques for biological detection of specific citrus graft transmissible diseases. pp. 35-45. Greening. Food Agric. Organ., Rome.

Salibe, A. A. and R. E. Cortez. 1966. Studies on the leaf mottling disease of citrus in the Philippines. Food Agric. Organ. Plant Prot. Bull. 14: 141-144.

Tsai, J. H. and Y. H. Liu. 2000. Biology of *Diaphorina citri* (Homoptera: Psyllidae) on four host plants. J. Econ. Entomol. 93: 1721-1725.

Tsai, J. H., J. J. Wang, and Y. H. Liu. 2002. Seasonal abundance of the Asian citrus psyllid, *Diaphorina citri* (Homoptera: Psyllidae), in southern Florida. Florida Entomol. 85: 446-451.

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