Biology and Management of the Asian Citrus Psyllid, *Diaphorina citri* Kuwayama, in Florida Citrus[1]

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The Asian citrus psyllid (ACP), *Diaphorina citri*, Kuwayama, (Homoptera: Psyllidae) is a well-established pest of citrus in Florida. Shortly after the psyllid was first discovered in Florida in 1998, it was determined to be distributed throughout the citrus-growing areas of the state, making eradication impossible (Halbert and Manjunath, 2004). Since its establishment, the Asian citrus psyllid has been considered a pest of moderate significance in Florida citrus. Direct damage caused by psyllid feeding is restricted to young tender leaves, thus control measures were previously only justified for non-bearing citrus which produce flush throughout the growing season. The discovery of citrus greening disease in Florida in August 2005 has changed the status of the psyllid, which is a vector of this pathogen, from a pest of moderate importance to one requiring management in all stages of citrus production. No control method will totally eliminate psyllids and the risk of pathogen transmission within a grove. Implementation of IPM practices to suppress the overall psyllid population will likely help slow the spread of the disease and maintain the economic feasibility of citrus production. Development of such a program requires knowledge of the biology of the pest, including factors that regulate psyllid populations, and available control options.

Identification and Biology

Adults

Adult psyllids (Fig. 1) are 3 to 4 mm in length with mottled wings held "roof-like" over the body (Mead, 1977). When young, tender flush is present, adult psyllids are commonly found aggregated on this new flush where they feed and mate (Fig. 2). After mating, the female psyllid must feed on young flush to produce mature eggs. Gravid females have an orange abdomen (Fig. 3) indicating that eggs are ready to be laid. Eggs are inserted into the leaf tissue inside the folds of the unexpanded leaves, on the edges of young leaves, or at the base of leaf buds which have just begun to form. When young flush is not available, psyllid adults can usually be found on the underside of leaves feeding in the area of the leaf midvein.

The average lifespan of an adult female psyllid is 30 to 50 days when temperatures are between 68 to 86°F with the average lifespan increasing as temperatures become cooler (Liu and Tsai, 2000). For example, at 68°F, the average lifespan of a female psyllid is 50.6 days. However, during the winter months when temperatures are 55 to 60°F, the average longevity of adult psyllids increases to 88 days.

1. This document is ENY-739, one of a series of the Entomology and Nematology Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Original publication date June 2006. Revised March 2007. Reviewed June 2012. Visit the EDIS website at http://edis.ifas.ufl.edu.

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Figure 1. Adult Asian citrus psyllid.

Figure 2. Aggregation of adult psyllids feeding on young leaves.

Figure 3. Gravid adult female (note the orange colored abdomen).

Adult psyllids survive for long periods on mature leaves until new flush is present. The ability to survive on mature leaves in the absence of new flush allows psyllid adults to over-winter and populations to build up quickly on the early spring flush.

Eggs

Eggs of the Asian citrus psyllid are almond- shaped and measure about 0.3 mm long (Fig. 4). When first laid, eggs are pale in color but gradually turn dark yellow to orange as they reach maturity and the psyllid nymphs are ready to emerge (Mead, 1977). When laid, the stalked anterior (front) end of the egg is anchored into the plant tissue. Surveying for psyllid eggs is best accomplished using a hand lens to examine the feather leaf stage flush as it begins to expand, making certain to look between the leaf folds to inspect thoroughly the hidden areas where most eggs are deposited. The egg stage lasts an average of 3 to 4 days when temperatures are 75 to 85°F, but can last as long as 9 days when temperatures drop below 60°F for an extended period of time (Liu and Tsai, 2000).

Figure 4. Psyllid eggs and 1st instars on unexpanded leaves (50x magnification).

Nymphs

Psyllid nymphs range in size from 0.3 mm long in the first instar to 1.6 mm long as fifth instars (Mead, 1977). The duration of the nymphal stage is about 12 to 14 days at 82°F. Nymphs are yellow with red eyes and visible wing pads in larger nymphs (Fig. 5). Because of their small size, the early nymphal stages are easily mistaken for aphids. However, psyllid nymphs produce white waxy secretions (Fig. 6) which can be visible from a distance and thus provides an easy means of distinguishing them from aphids. These waxy secretions contain honeydew and may be found accumulating on the surfaces of leaves, but in most cases are either blown off the leaf surface by wind or consumed by foraging ants. Compared to adults, psyllid nymphs are relatively sessile and move only short distances on a branch when disturbed.

Figure 5. Fifth-instar psyllid nymph.

Figure 6. Psyllid nymphs producing white waxy secretions.

Figure 7. Damage to new leaves as a result of feeding by psyllid nymphs.

Figure 8. Witches' broom effect caused by psyllid feeding.

Figure 9. Dieback of new growth from feeding by psyllid nymphs (note the white cast-skins where nymphs molted to adults).

Psyllid Feeding Damage

Psyllids, like other Homoptera, have piercing- sucking mouthparts used for feeding on plants. Feeding by psyllid adults and nymphs causes newly forming leaves to twist and curl similar to feeding damage from the green aphid (Fig. 7). Psyllid feeding also results in reduction of shoot length giving a witches' broom effect (Fig. 8). If heavy feeding occurs early on the developing flush, the new flush will fail to develop or abort (Fig. 9). In addition to direct feeding damage, honeydew inside the white waxy secretions produced by the nymphs promotes the growth of sooty mold which can reduce effective leaf area for photosynthesis (Fig. 10).

Figure 10. Accumulation of waxy secretions produced by psyllid nymphs on leaves.

Pathogen Transmission

Citrus greening disease is caused by a bacteria that is found in the phloem system of the plant. Many of the details regarding transmission of the citrus greening pathogen by the Asian citrus psyllid are still unclear (Halbert and Manjunath, 2004). Previous studies on psyllid-pathogen transmission suggest that a healthy psyllid feeding on a greening-infected plant may acquire the pathogen with as little as 30 minutes of feeding (Roistacher, 1991). There then follows a latent period of up to 25 days during which the bacteria multiplies within the psyllid and spreads to various tissues including the salivary glands. Few adults survive long enough to complete this latent period, but nymphs may acquire the pathogen and later transmit it as adults. Therefore, psyllids that develop on infected trees are more likely to be infected than adults who only feed on infected trees and move on. Transmission of the pathogen is thought to occur through salivary secretions, requiring 5 to 7 hours of feeding for successful transmission to occur (Xu et al., 1988). More detailed studies are needed to confirm these reports and determine the exact nature of transmission and whether psyllid-pathogen transmission might be minimized by the use of insecticides.

Management

The presence of greening in Florida citrus creates a new situation where psyllid management is of primary importance for managing this new disease. In other regions of the world where citrus is grown and greening disease is present, use of insecticides to control the psyllid vector has been a major component of greening management strategies. There are virtually no reports of successful control of greening in Asia where the disease is endemic. However, a related disease in South Africa vectored by a different psyllid species, *Trioza erytreae*, is said to be managed successfully by a combination of tactics including insecticidal control In contrast, control of both diseases transmitted by both vectors on Reunion Island has been attributed primarily to biological control (Aubert et al., 1996). However, it should be noted that complete elimination of the disease from an area has never been achieved.

Because psyllids and the disease are now permanently established in Florida citrus, the goal of psyllid management is suppression of psyllid populations, not total eradication of the insect or pathogen. To effectively maintain psyllids at low levels throughout the year, it will be necessary to incorporate chemical, cultural, and biological control into a comprehensive management strategy for psyllid suppression. No one management strategy alone is likely to be able to provide the results desired in terms of reducing psyllid populations. Thus, managing psyllids will involve targeting control measures at appropriate times depending on the particular growing situation. Currently, work is underway to better define management strategies for psyllid control that will prove to be economically feasible in terms of reducing the spread of citrus greening while maintaining the profitability of citrus production.

The two main factors that affect psyllid reproduction and growth are 1) presence of new flush and 2) temperature. New flush is required for psyllid females to lay eggs as well as for subsequent development of the psyllid nymphs. When no new flush is present, psyllid populations can only decline. Temperature is also closely linked to the abundance of psyllids in the field. The ideal temperature conditions for psyllids are between 68 to 86°F. At these temperatures, a single female psyllid lives for 30 to 50 days and can lay between 300 and 750 eggs. When the sustained daily temperatures are above 90°F, the average lifespan of a female psyllid decreases to less than 30 days with an average of fewer than 70 eggs produced per female. Thus, under Florida conditions, psyllid reproduction should be substantially reduced during the mid summer months due to both high temperatures and a reduced amount of new flush available for egg laying. If insecticides are to be used for psyllid suppression, they should be applied earlier in the year when conditions are favorable for rapid buildup of psyllid populations. During the summer months, when temperatures and flush patterns are not favorable for psyllid development, insecticide applications made solely for psyllid management are less likely to reduce psyllid populations. Predators and parasitoids of the psyllids are more likely to provide sustained control during these periods of low psyllid populations.

Management of greening must include propagation of disease-free nursery stock, removal of greening-infected trees, and control of psyllid populations. Action should be taken at each stage of the citrus production system to reduce psyllid populations and thereby limit the negative impacts of this new disease on Florida citrus.

Nursery Stock

Starting with clean trees is a must to keep greening out of groves. Therefore, budwood and nursery stock need to be protected from psyllids. Screenhouses can provide most of the necessary protection from psyllids and other pests. Antivirus insect netting that will exclude melon aphid (thorax width usually more than 300 mμ) will easily keep out psyllids and citrus leafminer, reducing risk from citrus tristeza and canker as well as greening. Inevitably, stray pests will manage to enter such structures. Use of an approved systemic insecticide in the potting medium will provide further protection against these pests, thus minimizing the risk of infected nursery trees being moved to groves where the disease is not present.

Nonbearing Trees/Resets

Young trees that produce multiple flushes throughout the year are at greater risk of greening infection than mature trees because of the attraction of adult psyllids to the new flush. Even without greening, young trees in the field need to be protected for about 4 years from psyllids and leafminers to grow optimally. Soil-applied systemic insecticides will provide the longest lasting control of psyllids with the least impacts on beneficials. Drenches are best applied once in the spring and possibly again in the fall, when the trees are flushing most and rainfall is less likely to move the material past the root zone before it can be taken up by the plant. Foliar sprays with different types of materials including petroleum oil can be used during the rainy season if psyllids are observed on the new flush of young trees. When making multiple foliar insecticide applications within a season for psyllid control, rotate between products with different modes of action to reduce the likelihood of pesticide resistance development.

Bearing Trees

Management options for psyllid control on mature trees are much more limited than for smaller trees. Currently, the only soil-applied insecticide that has been shown to provide reduction in psyllid numbers on large trees is aldicarb. If aldicarb is applied to mature trees as a part of a program for psyllid management, application should be made about 30 days prior to the initiation of flushing. This timing will allow for the material to move from the roots up to the tree canopy.

At present, the only other chemical control option for suppressing psyllids on mature trees is the use of broad-spectrum foliar insecticide applications. Recommended products for psyllid control are listed in the chapter on Asian Citrus Psyllid and Citrus Leafminer (ENY-734) in the current edition of the Florida Citrus Pest Management Guide (SP43). If greening is present in a grove or nearby, the best timing of foliar sprays for psyllid control is during the early season flush periods when temperatures are at or below 90°F and psyllids are most abundant. Foliar sprays should be timed to the presence of feather-leaf flush. Successfully controlling psyllids with foliar sprays on large trees after the spring flush is difficult because of the unsynchronized sporadic flushing patterns within a grove and the short-residual effects of these foliar sprays. Successful suppression of psyllids during the early part of the year may result in lower populations throughout the rest of the summer when psyllid populations do not develop rapidly due to the higher temperatures, limited availability of new flush, and to abundant natural enemies.

Biological Control

Foliar insecticide applications should be used sparingly to minimize the impact on natural enemies that maintain psyllids at lower levels later in the year. While a single female psyllid can lay as many as 800 eggs, studies in Florida and Puerto Rico have shown that over 90% of

Figure 11. Psyllid nymph parasitized by *Tamarixia radiata* (nymph flipped over to show developing parasitoid).

psyllids that hatch in the field do not survive to become adults. Many are consumed by predaceous insects such as ladybeetles (Michaud, 2004). The parasitic wasp, *Tamarixia radiata*, (Figs. 11 and 12) has been released in Florida and also contributes considerable mortality in some locations. Additionally, there are many potential pests such as scales, mealybugs, whiteflies, etc. that are generally innocuous in Florida citrus, due to biological control. Excessive sprays could easily result in resurgence of psyllids and other pests.

Figure 12. Remains of psyllid nymphs parasitized by *Tamarixia radiata* (note parasitoid emergence holes).

Other Management Considerations

In groves where citrus greening has been confirmed, trees showing signs of infection should be removed quickly. Foliar insecticides that provide quick knockdown of psyllids should be sprayed on the infected tree(s) prior to removal to prevent further spread of the disease by psyllids. Otherwise, the greening-infected psyllids will disperse from the tree(s) being removed and infest nearby healthy trees. Be sure to follow re-entry interval (REI) directions on the pesticide label. Trees in the immediate vicinity of infected trees should be considered higher risk due to increased likelihood of infection and receive extra scouting and treatment if necessary.

Management practices used within a grove can also affect psyllid populations, especially those practices that promote new flush such as hedging and topping and fertilization. Management strategies that reduce or limit the duration of flush, may help to keep psyllid populations at low levels and reduce the need for additional pesticide applications. Alternate host plants surrounding citrus can serve as a source of psyllids for infestation. Two common host plants include orange jessamine (*Murraya paniculata*) and box orange (*Severinia buxifolia*). Orange jessamine is a preferred host plant for psyllids but has not yet been proven to be a host for the strain of greening disease found in Florida. Box orange is also a host for the psyllid and is also a host for the greening pathogen (Hung et al., 2000). When possible, both of these plant species should be removed from areas surrounding commercial citrus groves.

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