BIOLOGY, HISTORY AND WORLD STATUS OF Diaphorina citri

David G. Hall

USDA-ARS, U.S. Horticultural Research Laboratory
2001 South Rock Road
Fort Pierce, FL 34945
e-mail: David.Hall@ars.usda.gov

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ABSTRACT

The asian citrus psyllid *Diaphorina citri* Kuwayama, is an important pest of citrus because it transmits phloem-limited bacteria (*Candidatus* Liberibacter spp.) responsible for citrus greening disease (huanglongbing), considered by some to be the world's most serious disease of citrus. The psyllid has slowly spread throughout southern Asia, the Saudi Arabian Peninsula, to some islands in the Indian Ocean, and to Reunion and Mauritius to the east of southern Africa. Huanglongbing has also spread throughout most of these regions. *D. citri* was first reported in the Americas in Brazil during the 1940s, but huanglongbing was not observed in Brazil until 2004. Since the 1990s, the psyllid has invaded a number of New World countries in the Caribbean, West Indies, and North and Central America including the United States (Florida and Texas) and Mexico. So far in these newly-invaded New World countries, huanglongbing has only been detected in the United States (Florida), where it was first found during 2005. Subsequent surveys revealed the disease was already fairly widespread in Florida. Some speculate that the disease was introduced into Florida before the psyllid invasion. Other citrus producing areas in the United States and citrus industries in Mexico and other areas where the psyllid now occurs are rightfully concerned about the disease. The Brazilian citrus industry and a number of citrus growers in Florida have adopted a three-component management program against huanglongbing: intensive chemical control of the psyllid, aggressive removal of trees symptomatic for the disease, and the planting of disease-free nursery stock. In spite of the three-component management program in Florida, hundreds of thousands of trees that were probably infected before the program was implemented have now been removed. To what extent the program will negate incidence and spread of the disease in the future remains uncertain. This report presents an overview of *D. citri* with respect to morphology, biology, ecology, host plants, sampling methods, vector-pathogen interactions, and control.

BIOLOGÍA, HISTORIA Y SITUACIÓN MUNDIAL DE *Diaphorina citri*

Palabras Clave: Enfermedades de los cítricos, plagas de los cítricos, Huanglongbing, Psilidos; Diaphorina citri

RESUMEN

El psilido asiático de los cítricos *Diaphorina citri* Kuwayama, es una plaga importante de los cítricos porque transmite la bacteria limitada al floema (*Candidatus* Liberibacter spp.) responsable de la enfermedad enverdecimiento de los cítricos (huanglongbing), considerada por algunos a ser la enfermedad de los cítricos más seria a nivel mundial. El psílido se ha dispersado lentamente desde el sureste de Asia, la península de Arabia Saudita a algunas islas en el Océano Índico y de Reunion y Mauritania al este de África del Sur. Huanglongbing también se ha dispersado a través de la mayoría de esas regiones. *D. citri* fué originalmente reportado en América durante los años 40's en Brasil, pero huanglongbing no se observó hasta el 2004. Desde los años 90's el psílido ha invadido a varios países del Caribe, Las Antillas y norte y centro América, incluyendo los Estados Unidos de Norteamérica (Florida y Texas) y México. A pesar de esas nuevas invasiones en éstos países, huanglongbing solo ha sido detectado en los Estados Unidos de Norteamérica (Florida), donde se encontró durante el 2005. Consecuentes revisiones revelaron que la enfermedad estaba ampliamente distribuida en Florida. Algunos especulan que la enfermedad fué introducida a Florida antes de la invasión de psílidos. En otras zonas productoras de cítricos en los Estados Unidos de Norteamérica, la industria de cítricos en México y otras áreas donde el psílido está ahora presente están muy preocupados por la enfermedad. La industria de cítricos de Brasil y un número de productores en Florida, han adoptado un programa de manejo de tres componentes contra huanglongbing: Intenso control químico del psílido, remoción agresiva de los árboles sintomáticos de la enfermedad y la plantación de árboles de viveros libres de la enfermedad. En cumplimiento de éste programa en Florida, cientos de miles de árboles que fueron probablemente infectados antes que el programa fuera implementado están

siendo ahora eliminados. Sin embargo, la efectividad del programa sobre la incidencia y dispersión de la enfermedad en un futuro es incierta. Este reporte presenta un panorama de *D. citri* con respecto a su morfología, biología, ecología, plantas hospederas, métodos de muestreo, interacciones vector-patógeno y control.

INTRODUCTION

The Asian Citrus Psyllid, *Diaphorina citri* Kuwayama, is an important pest of citrus because it transmits phloem-limited bacteria (*Candidatus* Liberibacter spp.) responsible for citrus greening disease (huanglongbing), considered by some to be the world's most serious disease of citrus (McClean and Schwartz 1970, Bové 2006). The psyllid has slowly spread throughout southern Asia, the Saudi Arabian Peninsula, to some islands in the Indian Ocean, and to Reunion and Mauritius. Huanglongbing has also spread throughout most of these regions. *D. citri* was first reported in the Americas in Brazil during the 1940s (Costa Lima 1942), but huanglongbing was not observed in Brazil until 2004. Since the 1990s, the psyllid has invaded a number of New World countries in the Caribbean, West Indies, and North and Central America including the United States (Florida and Texas) and Mexico. So far in these newly-invaded New World countries, huanglongbing has only been detected in the United States (Florida), where it was first found during 2005. Subsequent surveys revealed the disease was already fairly widespread in Florida. Some speculate that the disease was introduced into Florida before the psyllid invasion. Citrus producers in Mexico, Texas, and other areas where the psyllid now occurs are rightfully concerned. Some citrus growers in Brazil and Florida have adopted a three-component management program against huanglongbing: intensive chemical control of the psyllid, aggressive removal of trees symptomatic for the disease, and the planting of disease-free nursery stock. The State of Florida imposed new, strict nursery compliant agreements to help ensure disease-free nursery stock, which has reduced the number of qualified sources for young trees and inflated prices. In spite of the three-component management program in Florida, hundreds of thousands of trees that were probably infected before the program was implemented have now been removed. To what extent the program will negate incidence and spread of the disease in the future remains uncertain. In the meantime, researchers in entomology, plant pathology, horticulture and plant breeding are urgently searching for breakthroughs in ways of reducing huanglongbing. Entomologists are in a discovery phase of research detailing information on the biology, behavior, ecology, and biological control of *D. citri* in hopes of finding weak points in psyllid populations that could be exploited to help curb disease transmission and to reduce the need for chemical control. Plant pathologists and entomologists are collaborating in epidemiology studies to better understand the relationship between infestation densities of *D. citri* and spread of the disease.

A good scientific overview of *D. citri* in relation to huanglongbing was presented by Halbert and Manjunath (2004). Husain and Nath (1927) presented a detailed overview of *D. citri* including its morphology, distribution, host plants, biology, ecology, behavior, damage, and control. Although the primary economic problem associated with *D. citri* is transmission of greening disease, even in the absence of the disease pathogen the psyllid is sometimes regarded an important pest in young trees, as flush infested by the pest can be rendered distorted with reduced growth (Michaud 2004).

Geographical Distribution. The geographical origin of *D. citri* is thought by some to be southern Asia, probably India. Mead (1977) listed the Far East as the geographical origin of the psyllid. The Asian citrus psyllid and citrus greening are found throughout Asia, in the Saudi Arabian Peninsula, and in some islands in the Indian Ocean. The psyllid is known to occur in China, India, Myanmar, Taiwan, Philippine Islands, Malaysia, Indonesia, Sri Lanka, Pakistan, Thailand, Nepal, Hong Kong, Ryukyu Islands, Afghanistan, Saudi Arabia, Réunion, and Mauritius (Mead 1977, Halbert and Manjunath 2004). The psyllid was known to be in South America in Brazil (Mead 1977) since the 1940s (Costa Lima 1942) and is known to occur in the States of São Paulo and Parana. During the 1990s, *D. citri* invaded the West Indies (Guadaloupe), Abaco Island, Grand Bahama Island, and Cayman Islands (Halbert and Núñez 2004), and it was found in Florida during 1998 (Tsai and Liu 2000). During 2001, the psyllid was found in the Dominican Republic, Cuba (Halbert and Núñez 2004), Puerto Rico (Pluke et al. 2008) and Texas (French et al. 2001). The psyllid has recently been reported in many new areas in the Americas including Mexico, Venezuela, Argentina (Halbert and Núñez 2004), Costa Rico, Belize and Honduras (unconfirmed reports).

Taxonomy. The genus *Diaphorina* (Hemiptera: Psyllidae) includes 74 described species (Loginova 1975, Hodkinson 1980). Synonymy of *D. citri* is discussed by Husain and Nath (1927). Two other *Diaphorina* species are known to feed and breed on citrus, *D. communis* Mathur in India and *D. auberti* from the Comores Island (Aubert 1987). Halbert and Manjunath (2004) discuss these and four other obscure *Diaphorina* species that have been associated with citrus or closely related plant species.

Description, life cycle and biology. Adult Asian citrus psyllids are small (2.7 to 3.3mm long) with mottled brown wings (Figure 1). The adults are active, jumping/flying insects and can readily fly short distances when disturbed. Adults may be found resting or feeding on leaves with their heads at the leaf surface and their bodies held at a 45° angle from the leaf surface (Figure 2). The psyllid is a sucking insect and thus inserts its mouthparts into plant tissue to feed. Adults feed on young stems and on leaves of all stages of development. Oviposition and development of immature *D. citri* are confined to young, tender flush leaves as described by Hall and Albrigo (2007). The psyllid's life cycle includes an egg stage (Figure 3) and five nymphal instars (Figure 4). The egg is anchored to plant tissue on a slender stock-like process (Tsai and Liu 2000) on one end in an upright position, and large numbers of eggs may be found on a single flush shoot. Nymphs feed on young leaves and stems, continuously secreting copious amounts of honeydew from the anus and a thread-like waxy substance (Figure 5) from circumanal glands (Tsai and Liu 2000), and black sooty mold develops on the honeydew deposited on lower leaves. Tsai and Liu (2000) reported that first instar nymphs were docile and moved only when disturbed or over-crowded.

Figure 1. An adult Asian citrus psyllid on citrus flush.

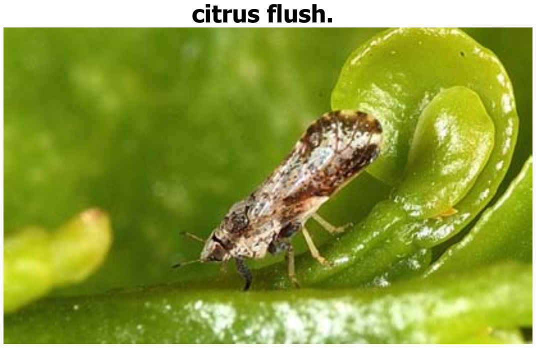


Figure 2. Adult Asian citrus psyllids on a mature citrus leaf.

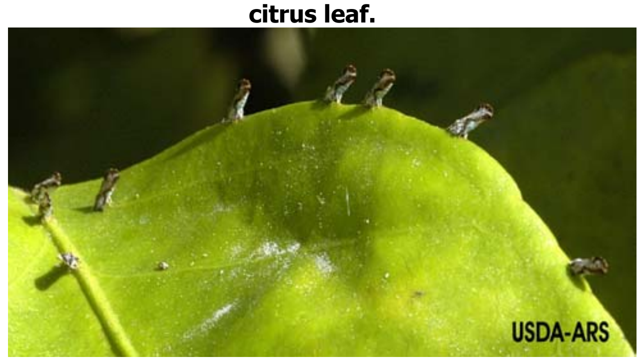


Figure 3. Eggs of the Asian citrus psyllid on citrus flush.

Figure 5. Nymphs of the Asian citrus psyllid with their typical white, waxy excretions.

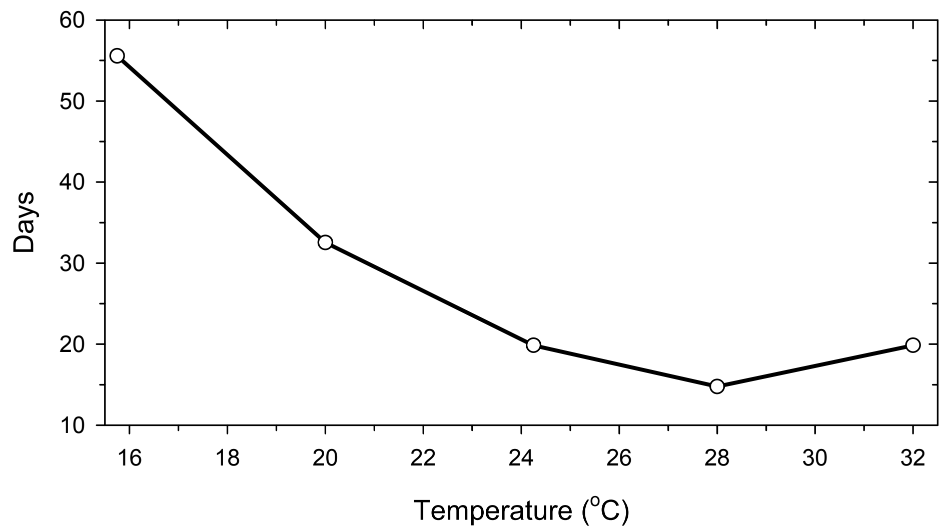
Figure 4. Nymphal instars of the Asian citrus psyllid.

The average size of an egg was reported to be 0.31mm long and 0.14mm wide (Tsai and Liu 2000), elongated and oval in shape. Eggs are light yellow when freshly deposited and bright orange with two distinct red eye spots at maturity. Nymphs are green or dull orange and feed on young leaves and stems. The first nymphal instar is 0.3mm long and 0.17mm wide with a light pink body and pair of red compound eyes (Tsai and Liu 2000). The second instar is 0.45 mm long and 0.25 mm wide; rudimentary wing pads are visible on the dorsum of the second instar's thorax (Tsai and Liu 2000). The third-instar averages 0.74 mm long and 0.43 mm wide, with well-developed wing pads and evidence of antennal segmentation (Tsai and Liu 2000). Third instar nymphs have 1 seta on each antenna (Husain and Nath 1927). Fourth instars averaged 1.01mm in length and 0.7mm in width, with mesothoracic wing pads extended toward one-third of compound eyes and metathoracic wing pads extended to the third abdominal segment (Tsai and Liu 2000). The fourth instar has two setae on each antenna (Husain and Nath 1927). Fifth-instars averaged 1.6mm long and 1.02mm wide, with the mesothoracic wing pads extended toward the front of the compound eyes and the metathoracic wing pads reaching the fourth abdominal segment (Tsai and Liu 2000). There are three setae on each antenna of fifth-instar nymphs (Husain and Nath 1927). In some mature nymphs, the abdominal color turned bluish green while in others the abdomen turned pale orange (Tsai and Liu 2000). Three more or less distinct abdominal colors are exhibited in adult psyllids: gray/brown, blue/green, and orange/yellow. Abdomen color was reported to be of no value in discerning the state of sexual maturity and of only limited value in discerning whether females have mated (Wenninger and Hall 2008a).

Developmental times of eggs and nymphs vary with temperature: at 25°C eggs hatch in 4 days and nymphs develop to the adult stage over a 13 day period for a total of 17 days from egg to adult (Tsai and Liu 2000). Mean development from egg to adult varied from 49.3 days at 15°C to 14.1 days at 28°C (Liu and Tsai 2000). Fung and Chen (2006) present developmental times for *D. citri* from oviposition to the adult stage at a range of temperatures. Extrapolations of data from Tsai and Liu (2000) and Fung and Chen (2006) were used to generalize developmental times from egg to adult at different temperatures (Figure 6). New adults reach reproductive maturity within 2 or 3 days, and oviposition begins about 1 or 2 days after mating (Wenninger and Hall 2007). The mean population generation time at 25°C therefore ranges from 20 to 22 days. Liu and Tsai (2000) reported that *D. citri* had optimal population growth potential at 25-28°C. Fung and Chen (2006) concluded that 24 to 28°C was the optimal temperature range for *D. citri*. *D. citri* fails to complete development at either

10 or 33°C (Liu and Tsai 2000). At 24°C, adult males live an average of 21 to 25 days and females live an average of 31 to 32 days (Nava et al. 2007). Maximum adult longevity ranged from 117 days at 15°C to 51 days at 30°C (Liu and Tsai 2000). McFarland and Hoy (2001) reported increases in *D. citri* survival with increasing relative humidity. A winter freeze of -3.3°C (duration not given) caused 94 to 96% mortality of adults in Japan (Ashihara 2004). Additional information on the biology of *D. citri* on different host plants and at different temperatures is provided by Nava et al. (2007).

Figure 6. Generalized *D. citri* developmental periods (days) from egg to adult at different temperatures.



Males and females find each other for mating in-part using substrate-borne vibrational sounds (Wenninger et al. 2008b). In addition, behavioral evidence indicates that females emit a sex pheromone, but none have yet been identified (Wenninger et al. 2008c). Males and females mate multiple times with different partners (Wenninger and Hall 2008d). Mating, oviposition and other movement activities by *D. citri* are restricted to daylight hours (Wenninger and Hall 2007). Aubert and Quilici (1988) reported a sex ratio of 49% males to 51% females. Females continuously lay eggs throughout their lives if young leaves are present. Adult females have been observed during their lifetime to lay 500 to 800 or more eggs over a period of two months with a maximum of 1,900 (Husain and Nath 1927, Pruthi and Batra 1938, Tsai and Liu 2000, Nava et al. 2007). Skelley and Hoy (2004) reported that adult *D. citri* ceased laying eggs when rearing temperatures reached 34°C for five days; once temperatures were reduced, the adults gradually began laying eggs again over 2-3 weeks. Psyllids produced fewer eggs when RH dropped below 40%.

Population fluctuations of the psyllid are closely correlated with the occurrence of new, young flush because eggs are laid exclusively on young flush and nymphs develop exclusively on flush. Large infestations of *D. citri* commonly occur during late spring through mid-summer, but outbreaks of the psyllid can occur at any time of the year depending on environmental conditions and the availability of young flush leaves (Hall et al. 2008a). Nine generations of *D. citri* were recorded over a one-year period in India on citrus, and it was speculated that two more generations could have occurred if more flush had been present during late summer and early fall (Husain and Nath 1927).

A report from China indicated flight activity by adult psyllids may occur all day long, however, it was pronounced during warm, windless, sunny afternoons between 4 and 6 pm (Aubert and Hua 1990). Speculations are that flying psyllids could be transported by wind drifts over a 0.5 to 1 km distance depending on wind speed and duration of sustained flight. Research in Florida indicated that low numbers of adult psyllids routinely disperse from citrus at least within distances of 8 to 60 m, and there was some evidence for occasional mass migrations (D. G. Hall, unpublished).

Host plants. The Asian citrus psyllid has a restricted range of host plants that includes citrus (*Citrus* spp), orange jasmine (*Murraya paniculata* (L.) Jack), orange boxwood (*M. koenigii* (L.) Sprengel), Chinese boxthorn (*Severinia buxifolia* (Poiret)) and other related species of Rutaceae (citrus plant family) (Mead 1997, Halbert and Manjanath 2004). Halbert and Manjunath (2004) present a list of 59 plant species reported as hosts, many of which have been confirmed. Citrus greening disease has been found in some non-*Citrus* species, but it is a direct economic problem only in *Citrus*. Since plants such as orange jasmine and Chinese boxthorn are grown as ornamental plants, regulatory efforts to limit spread of the psyllid and disease includes these plants and is thus negatively affects the ornamental plant industry in Florida. Although orange jasmine had not been considered a host of the Asiatic strain of the greening pathogen (Gottwald et al. 1989), recent reports by researchers in the United States and Brazil indicate this plant is at least weakly susceptible to the disease.

The development, longevity and reproduction of *D. citri* vary somewhat on different host plants (Tsai and Liu 2000, Fung and Chen 2006, Nava et al. 2007). The psyllid has displayed a higher rate of development on grapefruit than on rough lemon, sour orange or orange jasmine (Tsai and Liu 2000). The preferred host is thought by some to be *M. paniculata* (Aubert and Quilici 1988), an ornamental Rutaceaous plant found throughout the citrus belt in its native range and often planted in the southeastern United States. Based on their studies of *D. citri* in grapefruit and *M. paniculata*, Tsai and Liu (2000) and Tsai et al. (2002) concluded that *D. citri* did not prefer one host over the other (Tsai et al. 2002). However, continuous shoot flushes produced by *M. paniculata* could play an important role in maintaining high populations of the psyllid when new flushes are not available in citrus (Tsai et al. 2002). *M. paniculata* is considered more tolerant than citrus of direct feeding damage by the psyllid (Skelley and Hoy 2004).

Detection and Monitoring. Growers, researchers and regulatory personnel often need methods for detecting psyllids and monitoring their populations. Visual surveys by persons trained to recognize the different life stages of the psyllid may be the fastest way to detect an infestation. Young tender flush leaves of citrus or jasmine can be examined for adults, eggs and nymphs. Older leaves can be examined for adults. Adult psyllids can be monitored using yellow sticky traps hung directly in citrus trees (Hall et al. 2007a, Hall et al. 2008a). Yellow sticky traps have been useful for studying flight activity of *D. citri* (Aubert and Hua 1990). Catches of adults on yellow sticky traps suggested a flight activity which seemed more important at times for males than for females; such activity may result from short flight migrations toward sunny areas (Aubert and Quilici 1988). If desired, adult psyllids can be removed from sticky cards using lemon juice or a solvent such as heptane. A drop or two of the solvent is placed on the specimen, and within less than a minute the specimen can be moved with a brush from the card. Adults can also be monitored using tap sampling (Hall et al. 2007a). Although information on sampling to monitor infestations of *D. citri* in citrus is available, but no formal sampling recommendations have been developed. With respect to traps for adults, there is no attractant currently available for survey purposes.

Some information on sampling to estimate infestation densities in citrus (Dharajothi et al. 1989, Setamou et al. 2008) and in *M. paniculata* (Tsai et al. 2000) is available. Tsai et al. (2000) present information on sampling the psylid in *M. paniculata* using sequential estimation and presence/absence sampling. Dharajothi et al. (1989) sampled *D. citri* in citrus using a sample unit of one new shoot (4-5 cm in length). These researchers recommended that 40, 38 or 19 sample units per tree for eggs, nymphs or adults would provide a sufficient level of precision for a mean density prediction. Sampling for the immature stages and especially eggs is most critical with respect to most pest management decisions (Dharajothi et al. 1989). Eggs and nymphs were found to follow an aggregated dispersion among sampling units per tree while adults were found to more often follow a random dispersion (Dharajothi et al. 1989). Setamou et al. (2008) found the minimum number of flush shoots per tree needed to estimate *D. citri* densities varied from 8 for eggs to 4 for adults; projections indicated that a sampling plan consisting of 10 trees and 8 flush shoots per tree would provide density estimates of the three developmental stages of *D. citri* acceptable enough for population studies and management decisions. A presence-absence sampling plan with a fixed-precision-level was developed for citrus (Setamou et al. 2008).

In addition to basing psyllid densities on numbers per flush shoot, per leaf or per trap, some researchers have studied psyllid population densities using numbers observed per ten minutes (Aubert and Quilici 1988). A D-VAC collector (model 24) has been used to collect and count adult psyllids (Aubert and Quilici 1988).

***Vector-pathogen interactions*.** Limited information related to acquisition and transmission of the huanglongbing bacterium by *D. citri* has been published (Capoor et al. 1974, Moll and Van Vuuren 1977, Xu et al. 1988, Huang et al. 1984, Hung et al. 2004, Brlansky and Rogers 2007). Nymph stage *D. citri* developing on trees infected by the pathogen can acquire the pathogen during the later instars of development, and new adults from these nymphs are infected and may immediately be able to transmit the disease. Fourth and fifth instar *D. citri* successfully transmitted the disease, but first to third instars did not (Xu et al. 1988). It is possible that most adult psylla in infected orchards have acquired the pathogen as 4^{th} or 5^{th} instar nymphs rather than as adults, thus creating a huanglongbing epidemic rapid in nature (Xu et al. 1988). Uninfected adult *D. citri* feeding on a diseased tree can acquire the pathogen. Acquisition times of between 30 minutes and 5 hours have been reported (Capoor et al. 1974, Xu et a. 1988). Brlansky and Rogers (2007) reported that, when *D. citri* were held in the laboratory on HLB-infected citrus plants, less than 5% of the psyllids tested PCR-positive for Ca. L. asiaticus after seven days and 20% to 30% tested positive after 30 days.

The pathogen multiplies in the vector and consequently, after acquiring the pathogen, adults remain infective throughout their life (Xu et al. 1988, Hung et al. 2004). After acquiring the pathogen, a latent period of up to 25 days may be required before an adult can transmit the pathogen. Moll and Van Vuuren (1977) reported a latent period in newly-infected adults of 21 days. Capoor et al. (1974) reported latent periods of 8-12 days. When single adults were transferred to healthy seedlings after an acquisition feeding, the disease was transmitted when the adults fed for 5 hr or 7 hr but not when they fed for 1 or 3 hr (Xu et al. 1988). Xu et al. (1988) reported no evidence for transovarial transmission, because when new nymphs from infected adults were reared on disease-free seedlings, none of the seedlings showed symptoms after one year. This conclusion regarding no transovarial transmission was in agreement with conclusions by Capoor et al. (1974). Hung et al. (2004) also reported that transovarial transmission does not occur.

In some transmission tests, transmission efficiency has been low even though numerous psyllids were used on one citrus seedling (Xu et al. 1988). Low transmission rates reported include 6.6% of 271 citrus seedlings (Anonymous 1977), 1.3% of 380 plants (Huang et al. 1984) and 12.2% of 329 citrus seedlings (Xu et al. 1985). However, huanglongbing often spreads quickly in a citrus planting, particularly if the planting is young (Xu et al. 1988). For example, 50 to 70% of the citrus trees in Guangdong and Fujian provinces of China became infected before they reached bearing age during epidemic years of 1981-1983 (Xu et al. 1988). Low transmission efficiency reported by some researchers was probably an artifact of 1) not all disease-source plants being infected, 2) plants used for inoculation were not in the most susceptible stage for infections, or 3) inoculated plants were held under conditions not conducive for symptom development (Xu et al. 1988). Noted is that early transmission studies were dependent on the development of disease symptoms; polymerase chain reaction techniques for identifying the pathogen were not available. In a more recent transmission study, Xu et al. (1988) demonstrated that one adult per plant (following a 20 day acquisition period) resulted in disease transmission to 80% of seedlings tested.

Vector Control strategies. Legal controls on the movement of plants infested by psyllids are the first line of defense in preventing spread of the psyllid and disease to new areas. Once a grove is infested, a management program for citrus greening disease will include specific strategies for the pathogen and specific strategies for the vector. An integrated pest management program for the psyllid in citrus using both biological and chemical control strategies is desirable. However, once a grove is infected by huanglongbing, biological control is usually not an acceptable disease management option (Yang et al. 2006). Some growers in Brazil and Florida have deemed intensive chemical control programs against the psyllid necessary, which negate biological control of the psyllid as well as other insect pests. Under these intensive chemical programs in conjunction with aggressive removal of infected trees, informal evaluations over time indicate reductions in increases in numbers of infected trees are being achieved in Brazil. Applying insecticides at critical flushing periods can greatly reduce overall infestation levels of the psyllid. Entomologists with the University of Florida currently recommend including an insecticide treatment during the winter to control adults, thus reducing new infestations during subsequent flushes. Insecticides such as imidacloprid (Admire and Provado), fenpropathrin (Danitol), aldicarb (Temik), chlorpyrifos (Lorsban), carbaryl (Sevin) and dimethoate are registered for Florida citrus (Browning et al. 2005) and have been shown to be effective for psyllid control. Thiamethoxam (e.g., Actara or Platinum) has been shown to be effective in research trials but is not currently labeled for Florida citrus. A recent set of insecticide recommendations for *D. citri* in Florida citrus was presented by Rogers (2008). Reducing or eliminating alternate host plants of *D. citri* in the vicinity of citrus may contribute to reductions in populations of the psyllid. A disease management program will probably be most effective if used as an area-wide effort across large areas of land.

Recent reports from Vietnam indicate that infestations of *D. citri* and, consequently incidence of citrus greening disease in citrus, are negated to a large extent when citrus is interplanted with guava, *Psidium guajava* L. (plant family Myrtaceae) (Beattie et al. 2006, Hall et al. 2007b, Hall et al. 2008b). These observations were made in high density plantings of citrus that were intercropped with guava at a one-to-one tree ratio (2.5 m row spacing, 2.5 m tree spacing along rows). Reasons why guava might reduce infestations of the psyllid on citrus have been speculated to involve either volatiles or plant toxins. Volatiles associated with guava may interfere with the psyllid's ability to locate and infest citrus grown next to guava. Toxins associated with guava might exist that negatively affect the biology of the psyllid, interfering with psyllid reproduction in citrus. In greenhouse studies conducted in Florida, significant reductions in infestations of adults sometimes occurred in cages containing both citrus and guava, but the levels of reduction were less dramatic than anticipated (Hall et al. 2008b). Verifying the Vietnamese guava effect may be dependent on field studies, which have been initiated in Florida.

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