

ECOLOGY OF THE INSECT VECTORS OF CITRUS SYSTEMIC DISEASES AND THEIR CONTROL IN TAIWAN

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ABSTRACT

*This Bulletin discusses the ecology of the Asiatic citrus psyllid (*Diaphorina citri*) in relation to epidemics of greening disease of citrus. The citrus brown aphid (*Toxoptera citricidus*) is briefly mentioned, together with control measures against both vectors. The female psyllid lays eggs only on the new shoots of its host plants. It is especially active during the spring flush. The females lay eggs repeatedly whenever new shoots are available. Citrus brown aphid, a vector of tristeza, is also most common during the spring flush. In Taiwan, psyllids complete 8 to 10 generations each year. Adults and 4 - 5th instar nymphs may acquire the pathogen from diseased plants after feeding for 30 minutes or longer. Transmission is persistent throughout the adult life span (ca. 3 to 4 months or longer). However, the virulence cannot be transferred to the progeny via eggs. The Bulletin describes control technology. The importance of skilled manpower, financial support from the government and sound legislation are also emphasized in implementing control programs.*

INTRODUCTION

Citrus greening, (also known as huanglungbin or likubin), and tristeza are important systemic diseases which have been devastating citrus production in Taiwan since the 1950s (Su and Chen 1991). Both pathogens can be transmitted by grafting and by propagation with infected plant material, as well as by insect vectors (Lin *et al.* 1973, Su and Chen 1991). A sound knowledge of the epidemiology of these diseases is an essential part of an integrated control program.

The coupling of three components in a pathosystem is required for the completion of a disease cycle and its spread. In this regard, we need to understand the behavior of the pathosystem in terms of interactions between the causal organisms, the host plants and the vectors under prevailing conditions. Theoretically, the destruction of any linkage

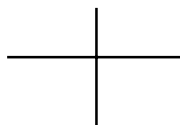
between two components would disrupt the coupling of the pathosystem and make it collapse—the aim of effective disease control. Several approaches have been taken in order to achieve control of greening disease and tristeza. These include the destruction and elimination of the sources of inoculum, the control of insect vectors, and renewal of orchards with healthy seedlings (Kotzé 1985, Su and Chen 1991). This Bulletin discusses mainly the ecology and control of the insect vectors.

ECOLOGY OF THE INSECT VECTORS

The Asiatic Citrus Psyllid (*Diaphorina citri* Kuwayama)

The psyllid is the vector of the citrus greening pathogen. This is a fastidious, Gram-negative bacterium which inhabits the

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phloem of citrus plants (Garnier *et al.* 1984, Huang *et al.* 1984). It mainly infests plants belonging to the Rutaceae family, especially citrus and jasmine orange (*Murraya paniculata* (L.) Jack) (Lin *et al.* 1973). This psyllid has been found in hot, dry areas of Southern China, and in Taiwan, Okinawa and the other southern islands of Japan, in the Indian Subcontinent, the western part of the Arabian Peninsula, Southeast Asia, Reunion Island, Mauritius and Brazil, (Aubert and Quilici 1984, Lin *et al.* 1973).

Three natural enemies are associated with the psyllid in Taiwan. Two of these are predators (*Chrysopa boninensis* and *Menochilus sexmaculatus*), while one is an endoparasitoid (*Diaphorencyrtus diaphorinae*) Lin *et al.* 1973. A nymphal ectoparasitoid, *Tamarixia radiata*, was introduced from Reunion Island during the mid-1980s into Taiwan, where it became established. It was introduced to enhance natural regulation of the psyllid population on jasmine orange (Chien *et al.* 1982). In addition, 11 hyperparasitoids which attack the parasitoids of the citrus psyllid are also present in Taiwan (Chien *et al.* *ibid.*, Chien 1992).

Life History and Habits

Female psyllids lay eggs only on the new shoots of the host plant. During her life span of 3 to 4 months, a female can lay eggs repeatedly, laying up to 200 - 800 eggs over an oviposition period of about 30 to 80 days. When temperatures are around 25°C, the egg incubation period is four days. The nymphs cluster beneath the leaves. They suck phloem sap from juicy leaves or petioles, and excrete white pellets or threads. These cover the shoots and dust the lower leaves, inducing the growth of sooty mold. It takes 15 days to complete the five nymphal instar stages. The preoviposition period is from 17 to 60 days (Lin *et al.* 1973, Tang and Su 1984).

The length of time between generations depends on the temperature. Xu *et al.* (1994) reported that it takes 53 - 59 days in the spring (March to May, mean 10-day temperature 19.6°C), 18 - 22 days in the summer (June to August, mean 10-day temperature 28°C), and 25 - 30 days in the autumn (September to November, mean 10-day temperature 24°C) to complete a generation.

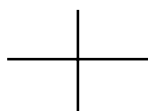
In general, psyllids can complete 8 - 9 generations each year in the northern part of Taiwan, and probably 10 or more in southern Taiwan (Lin *et al.* 1973). In Guangdong province of China, there are 11 - 14 generations each year, in Fujian province 6 - 7 on citrus and 9 - 11 on jasmine orange, while in southern Zhejiang there are 6 - 7 generations each year (Xu *et al.* 1994). The most favorable temperature range is 22 - 29°C. At temperatures below 20°C the psyllid population declines significantly, probably because of a lack of new shoots. The lethal temperature for nymphs is -3°C for 1 hr, and for the adults -10°C. Exposure to temperatures of -8°C for 6 days caused 91% mortality; while -10°C for 3 days produced 55% and for 5 days 89% mortality (Xu *et al.* *ibid.*).

Transmission of the Greening Bacteria

Citrus psyllids can transmit the greening pathogen despite a very low efficiency (c. 1%) (Huang *et al.* 1984). Both adult psyllids and the 4 - 5th instar nymphs are able to acquire the pathogen after feeding on a diseased plant for 30 minutes or longer. The pathogens remain latent inside the vector from between three to 20 days, after which they can be detected in the salivary gland. Inoculation feeding takes one hour or more. Once the psyllid vector acquires the pathogens, it can transmit them throughout its life span. However, it cannot transfer the virulence to its progeny via eggs (Xu *et al.* 1990). The latent period in citrus plants before symptoms are expressed ranges from four months to one year or more. Once infected, young plants die in two to four years (Huang *et al.* 1990).

Ecology of the Vector in Relation to Epidemics of the Disease

Adult citrus psyllids are found on citrus trees and jasmine orange plants all year round. They also lay eggs on plants throughout the year, whenever new flushes are available. The population density of eggs and nymphs is entirely dependent on the availability and abundance of new plant shoots. In Taiwan, the appearance of new shoots can be triggered by typhoon damage or by pruning. Irregular



fluctuations in psyllid populations were observed, corresponding to the flushing of new shoots (Lin *et al.* 1973, Tsai *et al.* 1984, Wang 1981). Under natural conditions, citrus trees in Taiwan have three flushes a year — in the spring, the summer, and the autumn. The relative abundance of psyllids falls with each flush (Wang *et al.* 1995, 1996). Thus, psyllid populations build up quickly from mid-March to reach a peak in late April to early May. Numbers then decline to reach a smaller peak in July, and an even smaller one in early November (Huang *et al.* 1990, Wang *et al.* 1995). Yellow sticky traps catch the highest number of adults from March to May, indicating that the most active egg-laying takes place in the spring flush (Wang *et al.* 1995). This is the most important time to apply chemical pesticides (Huang and Liaw 1995, Wang *et al.* 1995, 1996).

The transmission rate of greening is high in March, April, and May. A monthly infection test showed rates of 40, 33, and 20%, respectively. Under field conditions, if diseased plants and insect vectors are present, a plot with 30 healthy plants will show 57% infection within six months. A year later, 73% of trees will be infected, and two years later 100% will be infected, detected by indexing. In fact, the dispersal of psyllids through an orchard is rather slow. In a plot (30m x 15m) planted in 60 seedlings, psyllids released in February took about two months to spread over all the plot (Huang *et al.* 1990).

Wang *et al.* (1995, 1996) conducted an in-depth study of disease outbreaks, using a dot hybridization test with a DNA probe to detect greening organisms in psyllids and plants. In a 0.78 ha plot, 240 healthy Ponkan seedlings (1.8 x 1.8 m spacing) were planted in November, 1991. Psyllids were observed to have begun colonizing the plants five months later (April 25, 1992), with an infestation rate of 8%. A monthly survey showed that this had jumped to 23% in May and 73% in July. The use of DNA probes in July showed that 89% of trees were infected with the pathogen, and the disease incidence was 70%.

A re-infection test revealed that 2.5 years after planting, all Ponkan trees showed symptoms of greening. Of the 92 trees tested, 32% plants were infected. Six months later 55%, had the pathogen, and a year later

80% with a 33% disease incidence (Wang *et al.* 1996).

The Citrus Brown Aphid (*Toxoptera citricidus* (Kirkaldy))

Citrus tristeza can be transmitted by the citrus brown aphid, *Toxoptera citricidus*. Information about this vector is meager. It is widespread, being found in the southern provinces of mainland China, and in Taiwan, Korea, Japan, Okinawa, India, Sri Lanka, Philippines, Malaysia, Indonesia, Hawaii, South America, and Africa.

It occurs all year round. However, the aphids are most abundant in the spring and autumn. When citrus trees flush, the alate adults fly into the orchards, infesting the new shoots and producing nymphs by means of viviparity. The nymphs take 6 - 42 days to complete four molts before becoming adults. Each female can produce 5 to 68 nymphs. The adults live for 5 to 25 days. Alate forms appear as a result of crowding. The host plants include various species of the Rutaceae and Rosaceae families. The aphids mainly infest heart leaves and young foliage on a branch. They excrete honeydew which induces the growth of sooty mold.

There are many predators (Coccinellidae and Syrphidae) which attack this aphid, plus one parasitoid wasp. However, natural enemies have no significant impact on population levels (Tao 1980).

CONTROL OF THE VECTORS

Both the citrus psyllid and the citrus brown aphid first appear on host plants during the spring flush. Plants protected with methomyl or malathion sprays at 10-day intervals from March to May were not infected with citrus greening (Huang *et al.* 1990). In order to control both vectors at the same time, trees should be sprayed with 44% dimethoate EC, 50% malathion EC, and 40.64% carbofuran FP when flushes occur. Ten percent monocrotophos brushed onto the bark at the base of a branch at the onset of the spring flush is reported to give effective control of citrus leafminers, aphids, and psyllids without harming their natural enemies (Lin *et al.* 1973). Meanwhile, inoculative release of the ectoparasitoid, *Tamarixia radiata*

(Waterston), a nymphal parasitoid of the citrus psyllid, on jasmine orange plants, successfully keeps the psylla reservoir population down to a low level (Chien *et al.* 1989, Chien 1992).

CONCLUSION

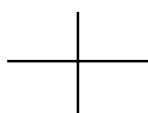
Technical know-how and information are the key to solving a disease problem. However, when it comes to extending technology to producers and keeping an integrated control program moving, other resources should be taken into consideration. First of all, we need enough qualified manpower to do the job in an organized and coordinated way. Skilled manpower is particularly needed for the production of pathogen-free seedlings, the monitoring of vectors, the early detection and destruction of infected plants, and the release of natural enemies (Chien 1992, Su and Chen 1991, Wang *et al.* 1995).

In addition, government policies should support the control program with adequate funding, and with pertinent regulations such as Taiwan's Seed and Seedling Act and the Plant Protection and Quarantine Act. These laws are indispensable for the regulatory control of pests. They enforce the destruction of inoculum sources (diseased plants and vectors) and established a certification system for pathogen-free planting materials.

Money certainly cannot solve every problem, but money makes it much easier to solve a problem. Finally, not only does the control technology and information need to be integrated and managed but also the manpower, the budget, and the regulations, so that they reinforce each other.

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