STUBBORN, GREENING AND RELATED DISEASES

Biological Control of the African and Asian Citrus Psyllids (Homoptera: Psylloidea), Through Eulophid and Encyrtid Parasites (Hymenoptera: Chalcidoidea) in Reunion Island

B. Aubert and S. Quilici

ABSTRACT. The principal damage of the leaf sucking citrus psyllids *Diaphorina citri* Kuwayama and *Trioza erytreae* (Del Guercio), is the transmission of a bacterium-like organism which threatens seriously the citrus production of Africa and Asia. The control of the two psyllid vectors is thus a most important priority for citrus production in these areas.

Two eulophid ectoparasites (super family of Chalcidoidea, O. Hymenoptera): *Tetrastichus dryi* Waterston and *Tetrastichus radiatus* Waterston, were introduced, bred and released in Reunion Island.

In the absence of hyperparasitism, the populations of the two psyllid vectors were reduced drastically 24 months after an original rate of release of 30 to 50 eulophid ectoparasites per square kilometer of the citrus area. A strongly limited population of the greening vectors is presently maintained.

Five non citrus Rutaceae, indigenous to the Island, or imported as ornamentals, were monitored regularly. Only *Murraya paniculata* harboured the Asian psyllid, *D. citri*.

Index words. psyllid vectors, greening disease, endo and ectoparasites of nymphs.

Until recently, the spread of the greening disease in Reunion Island was associated with severe outbreaks of the two psyllids: *Diaphorina citri* Kuwayama and *Trioza erytreae* (Del Guercio). Orchard populations of psyllids were originally controlled on this island by two main factors: climate, and flushing rhythm of the trees. Spraying of insecticides were irregular. Parasitoid insects, represented by five occasional predators were unable to reduce the psyllid buildups during the spring flush.

Hymenopterous primary parasites have been used for a program of biological control which was initiated at the end of 1974. This program has brought about a drastic reduction of the psyllid populations and significant improvements of orchard sanitation were subsequently obtained.

This paper deals with the evolution of *D. citri* and *T. erytreae* populations after the introduction and release of chalcid hymenopterous parasites originating from Africa or Asia.

PSYLLIDS FEEDING ON CITRUS IN REUNION ISLAND

The Oriental psyllid. The oriental psyllid, *D. citri*, tends to develop preferentially in hot and dry climates of the leeward side of Reunion, although it can also appear in the humid windward side. The nymphs which crawl and feed on young stems or petioles from the first to the fifth instars are fully exposed to environmental conditions. They excrete white pellets or threads which cover the shoots, giving the lower leaves the appearance of having been dusted. The nymphs pass through five moults and, on the fifth instar, give rise to adults. Adults feed generally, but not exclusively on the lower side of the leaves near the midrib. After

mating, the female lays from 200 to 800 eggs during its lifetime.

The African psyllid. Although the whole of Reunion is within the climatic range of *T. erytreae* (11), the African psyllid has been mostly observed in cool, moist areas of the Island above 500 m, with a marked preference for lemon shoots. After the second moult, the nymphs generally stop crawling and settle in galls or pits which they induce on the underside of the young leaves. Adults emerge after the completion of the fifth instar. The leaves which have supported the colonies of nymphs remain galled and curled. The female of *T. erytreae* is capable of laying up to 2500 eggs but usually no more than half this number is laid (1).

The winged adults of these two citrus psyllids breed exclusively on young shoots, the egg-laying process being stimulated by the presence of a new flush. The instar duration of both psyllids varies from 16-18 days up to 45 days or more under cool conditions. On dormant trees, adults are forced to feed on mature leaves and twigs. Their longevity is 3 to 4 months which provides good chances for becoming infectious. Due to the extreme fecundity of the females, phenomenally high populations may suddenly occur. The citrus psyllids are then able to exploit their environment in a relatively short period of time. They can breed on alternate non-citrus host plants belonging to the Rutaceae family.

Several inspections on indigenous Rutaceae of Reunion have not revealed individual host plants harbouring citrus psyllids. These indigenous plants included different *Evodia* species, as well as *Toddalia asiatica* (L.), *Xanthoxyllum heterophyllum* (Lam.) Smith, and *Vespris lanceolata* (Lam.) G. DON. The latter, which was recognized as attracting *T. erytreae* (18), is represented only by a few specimens in Reunion. Two imported Rutaceae can harbour *D. citri*: *Murraya koenigii* (L.) Spreng, the carry plant, and *Murraya paniculata* (L.) Jack. The latter, which is often used for ornamental hedges, can support large breeding colonies of the Asian psyllid on young shoots.

Before the implementation of biological control, adults and nymphs of a third psyllid: *Trioza eastopi* Orian were frequently observed on the citrus leaves. Winged adults of *T. eastopi* were also noticed feeding on avocado, papaw and vanilla leaves (3). *T. eastopi* has a marked preference for breeding on a Lauraceae: *Litsea chinensis* Jacq, which is a common weed shrub of the island. If the population reaches the stage of saturating the young flushes of *L. chinensis*, the females of *T. eastopi* will choose citrus leaves as oviposition sites. The nymphs of this polyphagous psyllid crawl but do not move down to the twigs. They usually remain on the underside of the young leaves and settle during the last instars in shallow pits. After the emergence of adults, the leaves remain gently curled. A survey made in 1975 showed that *T. eastopi* was distributed all over the island from low-lying areas up to 1000-1200 meters elevation. *T. eastopi* was apparently recorded in Reunion for the first time in 1898 on vanilla (8) and described later from Mauritius (19). Evidence of transmission of greening through this Litsea psyllid is still lacking. Adults of a fourth psyllid *Mesohomatoma lutheri* (Enderlein) have been seen on citrus leaves for short feeding periods, but this is an extremely rare occurrence. *Hibiscus* sp. is the preferential host of *M. lutheri*. The female of this fourth psyllid does not lay eggs on citrus flushes.

Eggs, nymphs and adults of

the three psyllids able to feed and breed on citrus are presented on fig. 1, together with a winged adult of *M. lutheri.*

PRIMARY PARASITES OF CITRUS PSYLLIDS

Eulophids. From an orchard survey made in 1973 (11), it became apparent that parasitized mummies of the citrus psyllids were non-existent on Reunion Island.

Two Eulophid parasites (superfamily Chalcidoidea; O. Hymenoptera) : *Tetrastichus dryi* Waterston and *Tetrastichus radiatus* Waterston, were introduced bred and released in Reunion (2, 3, 4, 14).

Both parasites were established in a self-perpetuating cycle with an original rate of release of 30 to 50 adults per square kilometer of citrus area. These two Eulophids have a similar biology and life history. The females lay eggs on psylla nymphs of the third, fourth and fifth instars. The larva is ectoparasitic and sucks out the body contents of the psyllid nymphs. Adults pupate in the mummy of the nymphs and emerge after 9 to 14 days by chewing a hole through the thorax of the host. *T. dryi,* a parasite of *T. erytreae,* was obtained from southern Africa, and *T. radiatus,* a parasite of *D. citri* from India. Adults of these two eulophids exhibit the same conspicuous dorsal white patch on the gaster; the tarsi of their legs having four segments.

Slight differences of the antenna distinguish the African from

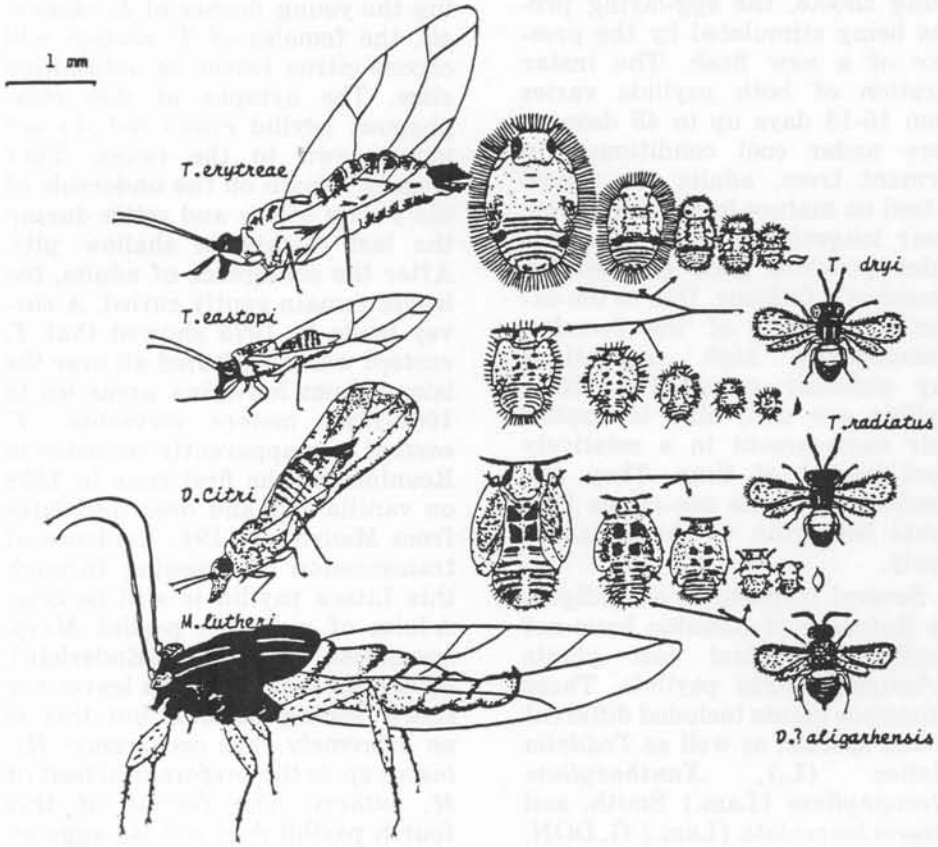


Fig. 1. Psyllids feeding and (or) breeding on citrus in Reunion Island, with the primary parasites presently established.

the Asian species. The males of *T. dryi* have a scapal sensorium situated further from the base of the antenna than that of *T. radiatus*. The males of the Asian hymenopteran have a scape and funiicle averaging the same length (23). Besides, the female of *T. dryi* has more slender funicle than *T. radiatus* and all three segments are subequal in size, each longer than wide (20) (fig. 2).

In 1978, an Eulophid parasite was discovered for the first time on mummies of *T. eastopi*. A first observation did not reveal any difference between this eulophid and *T. dryi*; Prinsloo who made a taxonomic study of this psyllid (non-published), found it to be conspecific with *T. dryi*.

Encyrtids. The African encyrtid, *Psyllaephagus pulvinatus* (Waterston), known as a primary parasite of *T. erytreae* was introduced bred and released in Reunion with rates as high as 250 adults per square kilometer of citrus area (14).

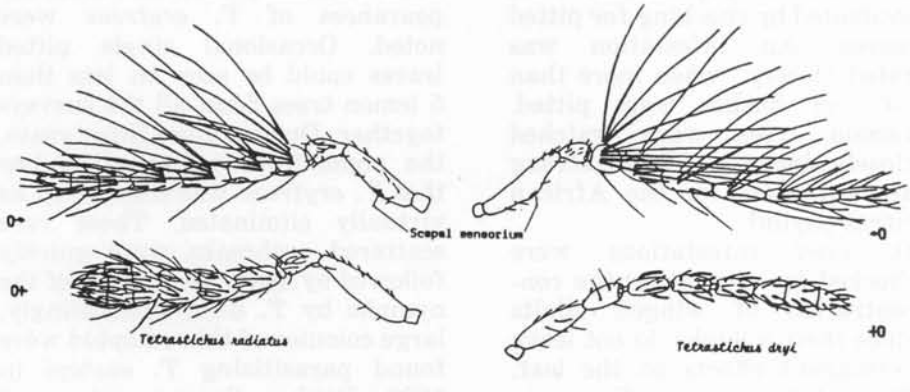
This endoparasite which develops internally on the second, third and fourth instar of psyllid nymphs could not establish on the Island and disappeared several months after being released.

The Asian encyrtid, *Diaphorencyrtus aligarhensis* (Shafee *et al.*), was discovered recently in Reunion. *D., aligarhensis* might have been mistaken for *Psyllaephagus harrisoni* Robinson, an African encyrtid formerly described in Reunion (14). *D.? aligarhensis* is a primary Asian endoparatise of *D. citri*.

The life cycle of *P. pulvinatus* is close to 20 days. Adults can emerge from the underside of the psyllid nymph or chew a hole through the thorax of the mummy. The biology of *D. aligarhensis* seems very similar of that of *P. pulvinatus*.

EVOLUTION OF CITRUS POPULATION AFTER THE INTRODUCTION OF FOREIGN CHALCIDOIDEA

Soon after the introduction of foreign chalcid hymenoptera, the infestations of psyllids were



	T. dryi	T. radiatus
♂	a/c ~ 3/4 b_3 ~ 1,2 b_2 ventral scapal sensorium in the middle of the scape	a/c ~ 1 b_1 ~ b_2 ventral scapal sensorium nearer the base of the scape
♀	funicle more slender. b_1, b_2 and b_3 subequal, each segment longer than wide	b_1 > b_2 > b_3

Fig. 2. Male and female antennae of *T. Radiatus* and *T. Dryi*. (After Waterston (23) and Prinsloo (20).

monitored both in citrus orchards and on wild or ornamental Rutaceae.

Orchard inspections: Material and Methods. The orchard inspections started on 15 ha in 1974, but larger areas were covered every year to reach a total of 200 ha by the end of 1982. Newly planted groves amounted to about 50 ha per year.

Six operators were trained for field surveys and were checked periodically for the accuracy of their inspection. Several growers were also shown the attacks of citrus psyllids and asked to indicate their observations.

Between January 1974 and January 1978, data was collected from the infested trees twice a year: early summer and early winter. From January 1978 only summer data were collected due to the decreased psyllid populations. This early summer checking was found to be representative since it included the spring outbreaks on the main flush of the year. The following procedure was then used:

—*T. erytreae* populations were evaluated by checking for pitted leaves. An infestation was rated "heavy" when more than 50% of flushes were pitted. Lemon trees were watched closely since they show a strong attractiveness for the African citrus psyllid.

—*D. citri* infestations were checked by estimating the concentration of winged adults since their nymphs do not leave permanent effects on the leaf. The adult concentration was rated "heavy" when a 5-minute sampling with a mouth aspirator collected 150 adults or more, and "low" when less than 10 adults could be collected in the same period of time.

Trees which supported the highest psylla infestations were noted for each orchard or a group of orchards.

During the spring flush, a few representative citrus zones were also examined weekly for the sequential appearance of psyllids and parasites. Samples of 50 parasitized nymphs were collected and hymenoptera emerging from the mummies were observed for species determination. Between November 1982 and January 1983 young shoots of *M. paniculata* harbouring *D. citri* nymphs were also sampled weekly to check the evolution of parasitism.

Results of orchard inspections. In the high-lying areas (above 500 m of elevation) a drastic reduction of *T. erytreae* infestations was noticed two years after the first release of *T. dryi*. Only lemon flushes exhibited curled leaves in a few scattered areas which were recorded on maps (fig. 3). One of these areas, situated at 900 meters of elevation in a very humid climate, showed low infestations of the African psyllid in January 1978 and January 1979. In 1980-81 and 1982, extremely rare and brief appearances of *T. erytreae* were noted. Occasional single pitted leaves could be seen on less than 5 lemon trees from all the surveys together. During these three years, the populations remained so low that *T. erytreae* was considered as virtually eliminated. These rare scattered outbreaks were quickly followed by heavy parasitism of the nymphs by *T. dryi*. Interestingly, large colonies of this eulophid were found parasitizing *T. eastopi* in 1980. During the campaigns of 1981 and 1982, *T. eastopi* dropped to extremely low levels on *Litsea* shoots, and this polyphagous psyllid was no longer observed feeding on citrus, avocados, vanilla or papaws.

Due to the low infestation of citrus pests (insects and mites) in