Attempts to Establish Tetrastichus Radiatus
Waterston (Hymenoptera, Chalcidoidea), A Primary
Parasite of Diaphorina Citri Kuwayama in Taiwan

Shui-Chen-Chiu, B. Aubert and Chin-Chin-Chien

ABSTRACT. In Taiwan, Diaphorina citri, the Asian vector of the citrus greening disease is
parasitized by a poorly effective endoparasite Diaphorencyrtus aligarhensis Shafee et al. In order
to achieve a more efficient biological control against the insect pest, several consignments of an active
ectoparasite, Tetrastichus radiatus, were dispatched from Reunion Island, with the intention of
establishing a new exotic natural enemy in Taiwan.
Index words. Asian citrus psylla, psylla parasitoids and hyperparasites, biological control.

Biological control of Diaphorina citri, the Asian greening vector, was
successfully implemented in Reunion Island some years ago, with the intro-
duction, and subsequent mass rearing
and release of a chalcidoid insect: Tetrastichus radiatus (1).

T. radiatus is a primary ectoparasite
with a short life cycle (9 to 14
days), belonging to the Eulophidae
group, and parasitizing D. citri
nymphs of the third, fourth and fifth
instars. The female has good searching
ability for locating its host. A
single egg is laid near the third coxae,
and the hatching larva will suck out
the body contents of the psyllid
nymph. At the end of the cycle, the
imagos emerge from the psyllid
nymph mummy by chewing a hole
through the thorax. The emergence
hole is typical of eulophid insects. T. radiatus is able to induce up to 93%
mortality (1). The insect is known so
far to parasitize only the Asian citrus
psyllid D. citri, and it was mistaken
for sometime with Tetrastichus dryi
Waterston, a parasite of the African
psylla (6).

Diaphorencyrtus aligarhensis,
another parasite of D. citri wide-
spread in Asia (7), has been described
from Taiwan under the name of Psyl-
laeaphagus diahorinae Lin et. al. (5).
It is an endoparasite belonging to the
Encyrtidae group with a comparatively longer life cycle (16-20 days).
The imagos generally emerges from
the psyllid nymph by chewing a hole
in the abdomen. D. aligarhensis
exhibits a conspicuous yellow band on
the gaster and is able to parasitize not
only D. citri, but also Diaphorina cardiae
Mathur (4) and Diaphorina aur-beri Hollis (2). However, the
percentage of mortality induced by D.
aligarhensis is rather low, generally
below 15%.

In order to achieve more efficient
biological control of D. citri, several
consignments of T. radiatus were dis-
patched from Reunion, with the in-
tention of establishing this new exotic
enemy in Taiwan.

MATERIALS AND METHODS

Tetrastichus radiatus was ob-
tained in Reunion from an insect-
tarium where a continuous supply of
D. citri nymphs is produced on Murraya paniculata (Lam) Jack. This
plant, currently known as orange jess-
samine, is one of the preferred host
plants of D. citri (1).

Two hundred potted seedlings
were used for this purpose; half for
the production of D. citri nymphs and
half for recycling the plants in the in-
sectarium after severe pruning to
produce new growth flushes. In
Reunion, T. radiatus is produced in
the absence of hyperparasites.

Leaflets of M. paniculata harbouring parasitized D. citri nymphs
were enclosed in hatching boxes and
dispatched by air mail to Taiwan. During the transport, emerging T.
TABLE 1
CONSIGNMENTS OF TETRASTICHUS RADIATUS FROM REUNION TO TAIWAN

<table>
<thead>
<tr>
<th>Date</th>
<th>Number of living parasites on arrival</th>
</tr>
</thead>
<tbody>
<tr>
<td>December 1983</td>
<td>0</td>
</tr>
<tr>
<td>February 1984</td>
<td>694.5</td>
</tr>
<tr>
<td>October 1984</td>
<td>596.5</td>
</tr>
<tr>
<td>May 1986</td>
<td>3299.5</td>
</tr>
</tbody>
</table>

T. radiatus had access to a small piece of blotting paper impregnated with honey. Few consignments were made as described in table 1.

Upon arrival, winged adults of T. radiatus were transferred to a quarantine room and enclosed with young potted citrus seedlings harbouring D. citri nymphs. After mass rearing and release, dispersal of T. radiatus in the open was checked either by recapturing the chalcidoid insect or by examining the thorax of the psylla mummies for typical exit holes.

For mass rearing in Taiwan, 800 potted citrus seedlings grown in the greenhouse were used as host plants. Individual seedlings were caged with 150 D. citri nymphs and 5 to 10 T. radiatus. Host plants were renewed regularly and there was no difficulty in maintaining the stock of T. radiatus for the subsequent release.

RESULTS

Releases. Releases were carried out in Taichung and Changwa counties between April 1984 and May 1986. In Taichung, 2,224 T. radiatus were liberated in 32 releases and in Changwa 234 T. radiatus were liberated in one release. Releases took place on M. paniculata hedges or backyard citrus trees not receiving chemical sprays.

Dispersal. The extent of dispersal can be seen in fig. 1. In Changwa, the insect was found to have dispersed 12 km from the release point of Tienwei. T. radiatus was also found in Chungshing village (Nantow County) approximately 15 km from the nearest release point.

Percentage of parasitism obtained on D. citri. In Wanfeng, 195 adult T. radiatus were released on M. paniculata hedges in November 1985. They were recovered in March 1986. The percentage of parasitism induced on D. citri was 17%. The highest parasitism recorded on D. citri nymphs feeding on M. paniculata was 36.4% in Tari and 28.9% in Wanfeng.

Parasitoid ecosystem of D. citri in Taiwan. The low percentage of parasitism by T. radiatus in Taiwan led us to examine some aspects of the

Fig. 1. Release and dispersal sites of Tetraastichus radiatus in Taiwan; ● = dispersal site (1986); ○ = release sites 1984 to 1986.
were carried to Changwá country and May 24 T. radiatus released and in us were liber-
Releases took 4a hedges or not receiving
nt of dispersal Wanfeng, 195 released on M. ovember 1985. n March 1986. sitism induced
The highest on D. citri A. paniculata 28.9% in Wan-
m of D. citri percentage of tus in Taiwan aspects of the

parasitoid ecosystem of D. citri on this island. Attention was focused on D. aligarhensis, and this chalcidoid insect was monitored between November 1984 and May 1986. The results, given in fig. 2, showed that a very high percentage of hyper-
parasitism occurred in December, with subsequent sharp decrease of D. aligarhensis populations between January and April.

Ten hyperparasites were obtained from D. aligarhensis (table 2).

Among these insects, one species, i.e. Packyneumron sp. (Pteromalidae), could oviposit and feed on T. radiatus in the laboratory.

CONCLUSION

The interesting dispersal of T. radiatus from its release points suggests that this eulophid ectopara-
site is probably established in Taiwan on D. citri. Nevertheless, mass rear-
ing is still continued to reach a total release of at least 8,000 individuals.

Fig. 2. Seasonal fluctuation of Diaphorencyrtus aligarhensis and its hyperparasitoids on Murraya paniculata in Taichung area.

<table>
<thead>
<tr>
<th>TABLE 2</th>
<th>PARASITOID COMPLEX OF DIAPHORENCYRTUS ALIGARHENSI S RECORDED IN TAIWAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Family</td>
<td>Parasitoids</td>
</tr>
<tr>
<td>Pteromalidae</td>
<td>Packyneumron apidis</td>
</tr>
<tr>
<td>Signiphoridae</td>
<td>Signiphora sp.</td>
</tr>
<tr>
<td>Aphelinae</td>
<td>unidentified a</td>
</tr>
<tr>
<td>Eulophidae</td>
<td>unidentified b</td>
</tr>
<tr>
<td>Encyrtidae</td>
<td>Tetraedricus sp.</td>
</tr>
<tr>
<td></td>
<td>Pseudalectra sp.</td>
</tr>
<tr>
<td></td>
<td>unidentified a</td>
</tr>
<tr>
<td></td>
<td>unidentified b</td>
</tr>
<tr>
<td></td>
<td>unidentified c</td>
</tr>
<tr>
<td></td>
<td>unidentified d</td>
</tr>
<tr>
<td>Total</td>
<td>50.19</td>
</tr>
</tbody>
</table>

(2,313)²

²Total number of D. aligarhensis individuals.
Whether *T. radiatus* will be able to reduce significantly the outbreaks of *D. citri* in the Taiwanese citrus orchards remains to be seen. The prerequisite for such a result is a very low percentage of hyperparasitism on *T. radiatus*. However, we have found that at least one hyperparasite of *D. aligarhensis* was also able to establish on *T. radiatus*. Thus, hyperparasitism could be a limiting factor for the biological control of *D. citri* in Taiwan.

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