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

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ABSTRACT. In Taiwan, *Diaphorina citri*, the Asian vector of the citrus greening disease is parasitized by a poorly effective endoparasite *Diaphorencyrtus aligarhensis* Shaffee *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 parasites and hyperparasites, biological control.

Biological control of *Diaphorina citri*, the Asian greening vector, was successfully implemented in Reunion Island some years ago, with the introduction, 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 Eulophydae 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 imago emerges 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* widespread in Asia (7), has been described from Taiwan under the name of *Psyllaephagus diaphorinae* Lin *et. al.* (5). It is an endoparasite belonging to the Encyrtidae group with a comparatively longer life cycle (16-20 days). The imago generally emerges from the psylla 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 auberti* 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 dispatched from Reunion, with the intention of establishing this new exotic enemy in Taiwan.

MATERIALS AND METHODS

Tetrastichus radiatus was obtained in Reunion from an insectarium where a continuous supply of *D. citri* nymphs is produced on *Murraya paniculata* (Lam) Jack. This plant, currently known as orange jessamine, 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 insectarium 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

Date	Number of living parasites on arrival
December 1983	0
February 1984	6 ♀ 4 ♂
October 1984	5 ♀ 6 ♂
May 1986	32 ♀ 9 ♂

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

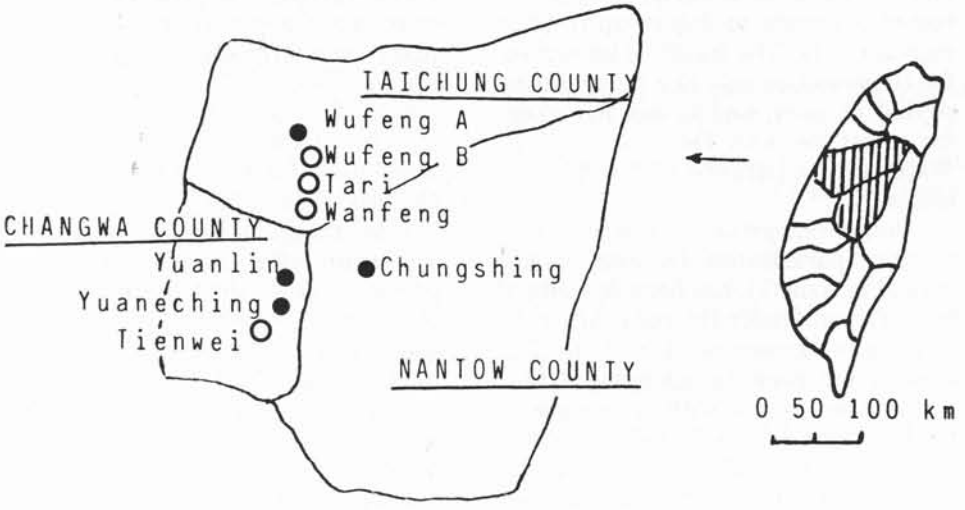

Fig. 1. Release and dispersal sites of *Tetrastichus radiatus* in Taiwan; ● = dispersal site (1986); o = release sites 1984 to 1986.

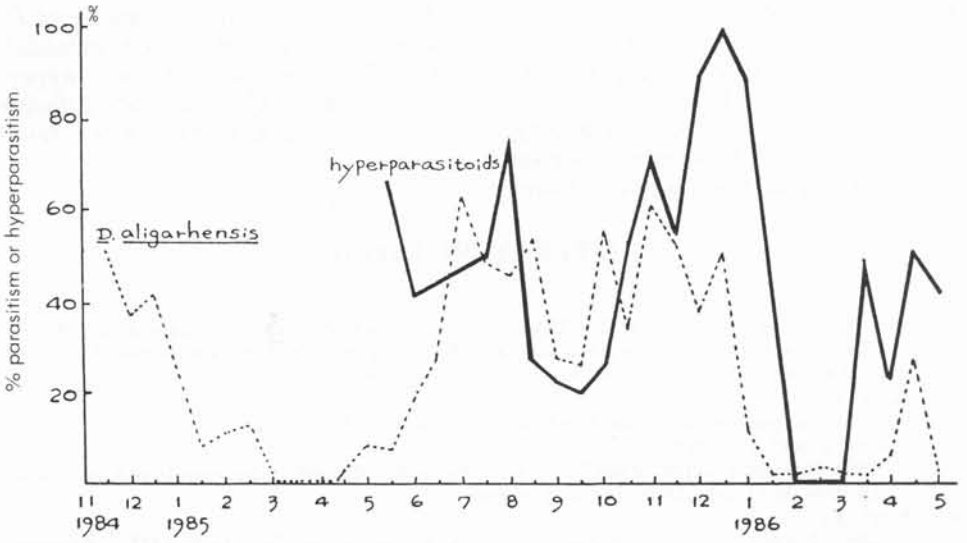

Fig. 2. Seasonal fluctuation of *Diaphorencyrtus aligarhensis* and its hyperparasitoids on *Murraya paniculata* in Taichung area.

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 hyperparasitism 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. *Pachyneumron* 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 ectoparasite is probably established in Taiwan on *D. citri*. Nevertheless, mass rearing is still continued to reach a total release of at least 8,000 individuals.

TABLE 2
PARASITOID COMPLEX OF *DIAPHORENCYRTUS ALIGARHENSIS* RECORDED IN TAIWAN

Family	Parasitoids	% of hyperparasitism on *D. aligarhensis*
Pteromalidae	*Pachyneuron apidis*	18.37
Signiphoridae	*Signiphora* sp.	13.44
Aphelinidae	unidentified a	0.73
	unidentified b	0.43
Eulophidae	*Tetrastichus* sp.	0.04
Encyrtidae	*Psyllaephagus* sp.	0.09
	unidentified a	16.73
	unidentified b	0.09
	unidentified c	0.04
	unidentified d	0.15
Total		50.19 (2,313)[z]

[z]Total 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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