

Proceedings of the 4th International  
Asia Pacific Conference on Citrus Rehabilitation  
Chiang Mai, Thailand, 4-10th Feb. 1990  
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## ON THE PARASITE COMPLEX OF *DIAPHORINA CITRI* KUWAYAMA (HOMOPTERA: PSYLLIDAE) IN ASIAN-PACIFIC AND OTHER AREAS

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### I. Introduction

The oriental citrus psyllid *Diaphorina citri* Kuwayama is an efficient vector of the Citrus Greening Disease (CGD), and has been responsible for much of the natural spread of CGD in citrus growing areas of Asia. The beneficial role of parasitic Hymenoptera for controlling this citrus psyllid has been seriously recognized since the successful implementation of biological control of *D. citri* in Reunion Island with the introduction of a chalcid parasite: *Tamarixia radiata* (Waterston). Other tentative programmes using this exotic parasites have been launched in several Asian Pacific countries (Chiu et al, 1988; Lama et al, 1988; Gavarra et al, 1989; Nurhadi, 1989). However, the major part of the success of these control programmes is based on sound knowledge of the indigenous parasite complex. This paper gives a brief account on parasitic Hymenoptera associated with *D. citri* in the Asian Pacific and other areas. It will present also some results of our survey on the parasitoid complex of *D. citri* in Fujian Province.

### II. A list of parasites of *D. citri* heretofore recorded in Asian Pacific and other areas.

Some 15 species parasites were known to be associated with *D. citri* in the Asia Pacific region. They belong to five families of Chalcidoidea, i.e. Eulophidae (2 species), Encyrtidae (more than 6 species), Signiphoridae (1 species), Pteromalidae (1 species) and Aphelinidae (5 species). The names (including synonymous names), parasitic types, distribution and references of these parasites are listed in detail in the Table 1. Unfortunately, among them only two species, an ectoparasite *Tamarixia radiata* (Waterston) and an endoparasite *Diaphorencyrtus aligarhensis* (Shafee, Alam and Agarwal), were recorded as primary parasites, the remaining 13 species acting as secondary or tertiary hyperparasites.

Table 1. A list of parasites of *Diaphorina citri* heretofore recorded in Asian-Pacific and other areas

Names of parasites	Parasitic types	Region	Reference
<b>Eulophidae</b>			
(1) <i>Tamarixia radiata</i> (Waterston) = <i>Tetrastichus radiatus</i> Waterston	primary	India Reunion* Saudi Arabia Mauritius* Nepal Taiwan* Mainland China Indonesia Thailand	Waterston (1922), Husain et al (1924) Etienne and Aubert (1980) Aubert (1984 a) Aubert (1984 c) Lama et al (1988) Chiu (1988) Tang (1989) Nurhadi (1989) Aubert (1989)
(2) <i>Tetrastichus sp.</i>	hyper- on T.R. and D.A. D.A.	Mainland China Taiwan Philippines	Tang (1989) Hayat and Lin (1988), Chien et al (1989) Balthasar (1990, unpublished))
<b>Encyrtidae</b>			
(3) <i>Diaphorencyrtus aligarhensis</i> (Shafee, Alam and Agarwal) = <i>Aphidencyrtus diaphorinae</i> Myartseva and Tryapitzyn = <i>Psyllaephagus diaphorinae</i> Lin and Tao  = <i>Aphidencyrtus aligarhensis</i> Shafee, Alam and Agarwal	primary	India Vietnam  Taiwan Comores Island Reunion Philippines  Mainland China Indonesia	Shafee et al (1975), Hayat (1981) Myartseva and Tryapitzyn (1978) Prinsloo (1985) Lin and Tao (1979) Aubert (1984 b) Aubert and Quilici (1984) Prinsloo (1985), Gavarra and Mercado (1989) Tang (1989) Aubert (1984), Nurhadi (1989)
(4) <i>Syrphophagus taiwanus</i> Hayat and Lin	hyper- on T.R. and D.A.	Taiwan Mainland China	Hayat and Lin (1988), Chien et al (1989) Tang (1989)
(5) <i>Ageniaspis sp.</i>	hyper- on D.A.	Taiwan	Hayat and Lin (1988), Chien et al (1989)
(6) <i>Cheiloneurus sp.</i>  = ? <i>Procheiloneurus sp.</i>	hyper- on D.A. ?	Taiwan  Philippines	Hayat and Lin (1988), Chien et al (1989)  Balthasar (1990 unpublished))
(7) ? <i>Psyllaephagus sp.</i>	hyper- on T.R. and D.A.	Mainland China Philippines	Tang (1989) Balthasar (1990, unpublished))
(8) Several unidentified	hyper- on D.A.	Mainland China	Tang (1989)
<b>Signiphoridae</b>			
(9) <i>Chartocerus walkeri</i> Hayat	hyper- on T.R. and D.A.	Taiwan Mainland China	Hayat and Lin (1988), Chien et al (1989) Tang (1989)
<b>Pteromalidae</b>			
(10) <i>Pachyneuron concolor</i> (Forster)	hyper- on T.R. and D.A.	Taiwan	Hayat and Lin (1988), Chien et al (1989)
<b>Aphelinidae</b>			
(11) <i>Coccophagus ceroplastae</i>	hyper- on D.A.	Taiwan	Hayat and Lin (1988), Chien et al (1989)
(12) <i>Coccophagus sp.</i>	hyper- on D.A.	Taiwan	Hayat and Lin (1988), Chien et al (1989)
(13) <i>Marietta leopardina</i> Motshulsky = <i>Marietta javensis</i> Howard	hyper- on T.R. and D.A. D.A.	Taiwan  Philippines	Hayat and Lin (1988), Chien et al (1989)  Balthasar (1990, unpublished))
(14) <i>Encarsia spp.</i>	hyper- on T.R. and D.A.	Taiwan Mainland China	Hayat and Lin (1988), Chien et al (1989) Tang (1989)
(15) An unidentified	hyper- on T.R. and D.A.	Taiwan	Chien et al (1989)

T.R. = *Tamarixia radiata* D.A. = *Diaphorencyrtus aligarhensis* \* = Introduced

### III. Impact of hyperparasites on the two primary parasites of *D. citri* in Fujian and Taiwan

Psyllid nymphs parasitized by the ecto- or the endo- parasites are reduced to their exoskeletons known as the mummies. The mummies of the ecto- and the endo- parasites have different forms. The psyllid mummy parasitized by the ecto- primary parasite *T. radiata* can be recognized by its dark brown, flatten body, and the parasite pupa remaining external and lying beneath the ventral surface of the host psyllid (Fig. 1). On the other hand, the mummies parasitized by the endo- primary parasite *D. aligarhensis* are usually brownish semi spherical and the parasite pupae remain enclosed within the host psyllid mummy. Furthermore, emergence holes are always typical of a given parasite. For example, the exit hole of *T. radiata* is always located on the dorsal side of the thorax (Fig. 2) while that of *D. aligarhensis* is located on the dorsal abdomen (Fig. 3) and those of the hyperparasites generally on the lateral side of the abdomen of psyllid nymphs. Assessment of parasitism or hyperparasitism can be made by examining the mummies as these structures always remain firmly attached to the leaf or the twigs of the host plant of *D. citri*.



g. 1: Egg (e) laid near the coxa of 3rd leg.



Fig. 2: Dorsal exit hole left by *Tamarixia radiata*



Fig. 3: Dorsal abdomen exit hole left by *Diaphorencyrtus aligarhensis*

During our survey period from August 1988 to December 1989, a total of 2,776 psyllid mummies parasitized by *T. radiata* were collected. Unfortunately, about 25% of them were found to be hyperparasitized by 5 species of hyperparasites and the dominant hyperparasite was *Tetrastichus* sp. (see Table 2). The average percentage of hyperparasitism of *T. radiata* by *Tetrastichus* sp. amounted to 21.82% and 28.65% respectively in 1988 and in 1989, and a maximum percentage reached 87.88% in a single sampling collected at Changtai of Fujian on August 21st, 1988. On the other hand, 765 mummies parasitized by *D. aligarhensis* were collected in this survey and 29.54% of them were hyperparasitized by 10 species of hyperparasites with a maximum percentage of 50% at Zhangzhou, Fujian on November 10th, 1989. The more common hyperparasites of *D. aligarhensis* were *Charotocerus walkeri*, ?*Psyllaephagus* sp. and *Syrphophagus taiwanus* in Fujian Province.

Interestingly, the situation of hyperparasitism associated with the two primary parasites of *D. citri* in Taiwan was quite different from that mentioned above in Fujian. According to the publication of Chien et al (1989), a total of 14,319 psyllid mummies parasitized by *D. aligarhensis* was collected from May 1985 to May 1988. Nearly 42.2% of them were found to be parasitized by 10 species of hyperparasites (Table 2) while a maximum percentage reached 88% in December, 1985 and January, 1986. The dominant hyperparasite was *Pachyneuron concolor*, a petromalid parasite which does not serve as hyperparasite of *D. citri* in Fujian. The secondly common hyperparasites were *Charotocerus walkeri* and *Syrphophagus taiwanus*. On the other hand, 11,342 mummies parasitized by *T. radiata* were collected in Taiwan from September 1986 to May 1988. Fortunately, only some 1% of them were hyperparasitized by 7 species of hyperparasites.

Table 2. Hyperparasites and their percent parasitism of *T. radiata* and *D. aligarhensis* recorded in Fujian and Taiwan

Hyperparasites	Percentage of hyperparasitism (%)					
	<i>T. radiata</i>			<i>D. aligarhensis</i>		
	Fujian (A) (1764)	Fujian (B) (1012)	Taiwan (C) (11342)	Fujian (A) (385)	Fujian (B) (380)	Taiwan (C) (14319)
<b>Eulophidae</b>						
<i>Tetrastichus</i> sp.	21.82	28.65	0.01	2.90	3.68	
<b>Pteromalidae</b>						
<i>Pachyneuron concolor</i>			0.45			18.50
<b>Signiphoridae</b>						
<i>Chartocerus walkeri</i>	0.08	1.09	0.03	9.26	13.16	13.50
<b>Encyrtidae</b>						
<i>Syrphophagus taiwanus</i>			0.05	1.09	4.21	6.80
? <i>Psyllaephagus</i> sp.	0.04	0.10		10.35	6.58	
<i>Cheiloneurus</i> sp.						0.01
<i>Ageniaspis</i> sp.						
unidentified sp. A				3.45	0.26	
sp. B				0.91		
sp. C				0.18		
sp. D				0.18		
<b>Aphelinidae</b>						
<i>Encarsia</i> sp. near <i>shafeei</i>			0.11			0.80
<i>Encarsia</i> sp. A	0.08	0.10		0.91	1.05	
<i>Encarsia</i> sp. B	0.22	0.20		0.91		
<i>Marietta leopardina</i>			0.25			2.50
<i>Coccophagus ceroplastae</i>						0.01
<i>Coccophagus</i> sp. unidentified sp.			0.05			0.10
						0.01
<b>Total</b>	22.24	30.14	0.95	30.14	28.95	42.24
	25.10			29.54		

A: Aug.-Dec. 1988 in Fujian (Tang, 1989)

B: April-Dec. 1989 in Fujian (Original)

C: May 1985-May 1988 in Taiwan (Chien et al, 1989)

#### IV. Conclusion

Associated with the citrus psyllid *Diaphorina citrus* (Kuwayama) in Asian Pacific region, are two primary parasites and 13 secondary and tertiary hyperparasites. One of

the primary parasites *Tamarixia radiata* (Waterston) remains external to the psyllid host whereas the other primary parasite *Diaphorencyrtus aligarhensis* (Shafee et al) is an internal parasite. The major secondary hyperparasite *Tetrastichus* sp., which was collected in a large number in Fujian Province, attacks both the primary parasites, whereas the important hyperparasites in Taiwan were *Pachyneuron concolor* and *Chariocerus walkeri*, both of which also can attack the 2 primary parasites. The higher percentage of hyperparasitism maybe reduces the impact of 2 primary parasites on the citrus psyllid in the 2 above mentioned region.

The primary ectoparasite, *Tamarixia radiata*, which was described originally by Waterston (1982) from Punjab India, has recently been recorded to be indigenous to Saudi Arabia (Aubert 1984), Nepal (Lama et al, 1988), Indonesia (Nurhadi, 1989), Mainland China (Tang, 1989) and Thailand (Aubert, 1989). However, not much information on the parasites of *D. citri* could be available in our five project countries except in Fujian and Taiwan. It is intensely recommended that preliminary survey on the complex of indigenous natural enemies of *D. citri* should be a prerequisite to biological control programmes against the vector in those countries, such as Malaysia and Thailand, which lack information on parasites of *D. citri*. We can at least expect *D. aligarhensis*, which is probably, according to Prinsloo (1985), widely distributed throughout the oriental region, to be also indigenous to these countries (Thailand and Malaysia).

### Acknowledgements

This study was supported by a grant from NSF of China. The author is greatly indebted to Prof. CHAO HSIN FU and Dr. B. AUBERT for their useful criticism and for going through the manuscript. Thanks are due to Mis CHEN JIU PING and Mr. GUO SONG SHENG for typing the manuscript.

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