BIOLOGICAL CONTROL OF CITRUS PSYLLID, *DIAPHORINA CITRI* IN TAIWAN

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ABSTRACT

Citrus psyllid, Diaphorina citri Kuwayama, a vector of citrus greening disease, is an insect pest of citrus. From 1983 to 1990 the Taiwan Agricultural Research Institute introduced Tamarixia radiata (Waterston) from Reunion and evaluated its efficiency against D. citri based on its controlling ability, synchronization with host, competition or synergism with Diaphorencyrtus diaphorinae (Lin and Tao), and parasitism by indigenous hyperparasitoids. The influence of a disturbed habitat on fluctuations in the population of D. citri and its parasitoids was interpreted, using biological data such as longevity, oviposition behavior and reproduction type. The use of parasitoids in the IPM system for D. citri and greening disease is discussed.

INTRODUCTION

The citrus psyllid, *Diaphorina citri* Kuwayama, damages citrus not only by direct feeding and the excretion of honeydew which causes sooting disease, but also by transmitting citrus greening (= huanglungbin, likubin) which seriously reduces the life of the citrus tree and threatens citrus production in Taiwan (Lin *et al.* 1973, Huang *et al.* 1984).

C. citri oviposits on the buds of host plants only, and is quite sensitive to chemicals. In controlled orchards, the psyllid population is very low and can be found only during the budding period in spring, summer and autumn. However, the jasmine orange (*Murraya paniculata* (L.) Jack) and abandoned orchards serve as reservoirs for psyllids. Natural enemies were therefore used in an attempt to decrease the psyllid density and reduce the transmission rate.

Five indigenous natural enemies of *D. citri*, including four predators — (*Mallada boninensis* (Okamoto), *Menochilus sexmaculatus* Fabricius, *Serangium* sp. and *Geocoris* sp.) — and an endoparasitoid (*Diaphorencyrtus diaphorinae* (Lin and Tao)) have been recorded in Taiwan (Lin *et al.* 1973, Chien 1992). The predators have little impact on *D. citri* (Lin *et al.* 1973). *D. diaphorinae* is widely distributed and is active in host searching. However, it scarcely occurs (parasitism less than 15%) from January to May (Fig. 1). This time lag results in the upsurge of *D. citri*. *D. diaphorinae* also suffers from the presence of indigenous hyperparasitoids (25% – 51%) throughout the island (Fig. 2) (Chien *et al.* 1988, 1989; Chien *et al.* 1991a).

Tamarixia radiata (Waterston), an Eulophid parasitoid of *D. citri*, originated in Pakistan (Waterston 1922). It was successfully established and later controlled the psyllid in Reunion Island (Aubert and Quilici 1984). The Taiwan Agricultural Research Institute introduced *T. radiata* from Reunion Island for the purpose of controlling citrus psyllid and reducing the transmission of citrus greening. A total of 62 adult parasitoids were obtained from 1983 to 1986 in four

Keywords: Biological control, *Citrus sinensis*, *Diaphorencyrtus diaphorinae*, *Diaphorina citri*, greening disease, IPM, *Murraya paniculata*, *Tamarixia radiata*

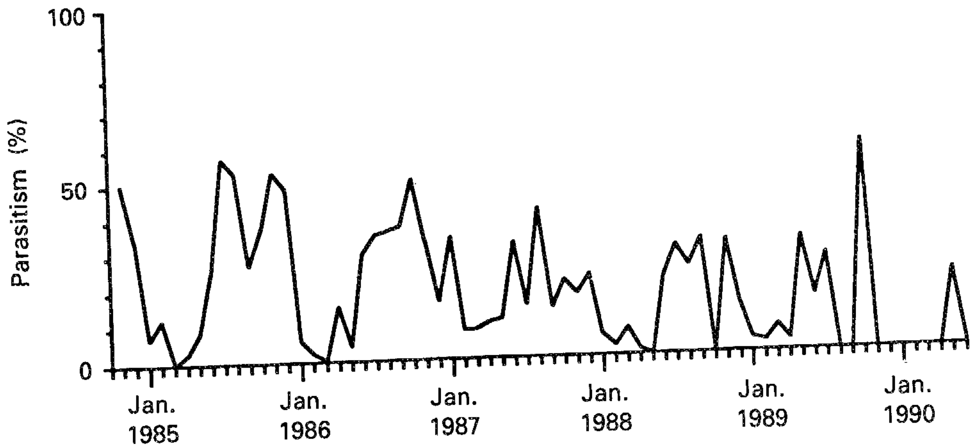

Fig. 1. Fluctuations in the population of *Diaphorencyrtus diaphorinae* on *Murraya paniculata* in Taiwan from October 1984 to June 1990.

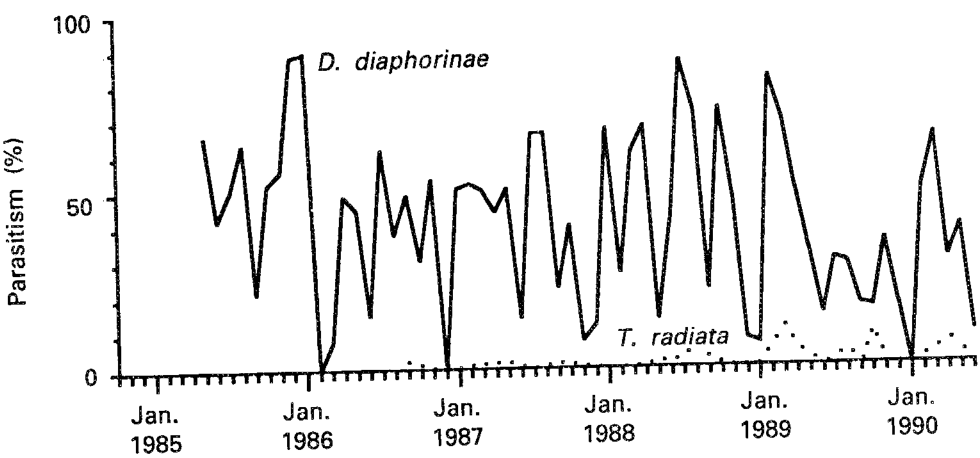

Fig. 2. Percentage of hyperparasitism on *Tamarixia radiata* and *Diaphorencyrtus diaphorinae* in Taiwan from May 1985 to June 1990.

shipments. A total of 21,164 adults of *T. radiata* were propagated and released into two citrus orchards and 39 sites of jasmine orange bushes in 13 counties during the period 1984 to 1988. It became established in November 1987 (Chien *et al.* 1988, 1989). The bionomics of *T. radiata* have proved it to be an efficient parasitoid of *D. citri* (Table 1) (Chien 1992, Chien *et al.* 1973).

EVALUATION OF THE EFFICIENCY OF PARASITOIDS AGAINST *D. CITRI*

Ability of Parasitoids to Control *D. citri*

Surveys were carried out from October 1987 to June 1990 on one site with potted jasmine orange, seven sites with hedges of jasmine orange, and two citrus orchards

Table 1. Population parameters of *Tamarixia radiata*

Items	Parameters	Condition
Intrinsic rate of increase, 1/day	0.3077	25°C, 20 hosts/day
Searching rate (both parasitized and host-feeding)	0.89	25°C, 3.5x20 cm, 24h
Handling time, min	$23.89+0.004N_t^2$	25°C, 3.5x20 cm, 24h
Lower developmental threshold, °C	11	egg — adult stage
Degree-day, °C-day	165	egg — adult stage
Host-killing capability, hosts/♀	$\hat{Y} = -21.005+18.197x-0.186x^2$, $R^2=0.91$	25°C, 3.5x20 cm, 24h, 1 — 80 hosts/day
Field parasitism (Feb—Apr), (%)		
Potted jasmine orange	80—99.7	1.0—5.2 hosts/10cm branch
	55—72	0.1 hosts/10 cm branch
Hedge of jasmine orange	58 — 95	1.3 — 3.4 hosts/10cm branch
	40	0.1 hosts/10 cm branch
Host utilization, %		
lifetime	90—94	25°C, 3.5x20 cm, 2—8 hosts/day
Most active oviposition period	87—90	25°C, 3.5x20cm, 14—20 hosts/day

(*Citrus sinensis* Osbeck) in central Taiwan (Taichung and Changhua) and southern Taiwan (Kaohsiung and Pingtung) where *T. radiata* was released. The number of *D. citri* (adults and nymphs) and mummies of *D. citri* (parasitized by both *T. radiata* and *D. diaphorinae*) were recorded to study fluctuations in the population of *D. citri* and its parasitoids, and to evaluate the parasitoids' efficiency against *D. citri* (Chien *et al.* 1991a). Due to differential host plants and management methods, the parasitoids have several efficiency levels against *D. citri*.

Significant Efficacy of *T. radiata* in a Stable Habitat of *M. paniculata*

The jasmine orange plants in pots or hedges surveyed in this study were located near Wufeng county and in six apartment blocks. The 80 pots (dia. 40 cm per pot) were arranged along the street (width 12 m) at 3 m intervals. The jasmine orange hedges were classified for management as having received no large-scale pruning or spraying of insecticides. People pruned the jasmine oranges near their houses by chance. In this stable habitat, the percentage of parasitism by *T. radiata* and *D. diaphorinae* was between 80% to 100% from February to April. For the rest of the year, the total percentage of parasitism was 32% to 80%. Over 94.6% (n = 13,270) of the parasitoid wasps collected in the field were *T. radiata* (Fig. 3). Because of the synchronization between *T. radiata* and *D. citri* in spring, this parasitoid could subsequently significantly suppress the rapid population growth of *D. citri*. There was a stable decrease in the *D. citri* population. In 1990, the psyllid densities on jasmine orange were 0.2 – 1.1 adults per 10 cm branch, and the average number of adults was higher than the average number of unparasitized nymphal psyllids (Fig. 3). One of the reasons for inducing this phenomenon was that the adults live longer (93.3 days) than the 5th or 4th and 5th instar nymphal stage (3.2 or 6.2 days) at 25°C (Tang and Su 1984). Another reason was that the adults have a tendency to aggregate. They could reach hundreds on one leaf (Lin *et al.* 1973) and the number is cumulative. This suggested that jasmine orange psyllids did not disperse at low densities of 0.2 to 1.1 adults per 10 cm branch, otherwise the number of nymphs would be higher than that of adults (Chien *et al.* 1991a, Chien 1992).

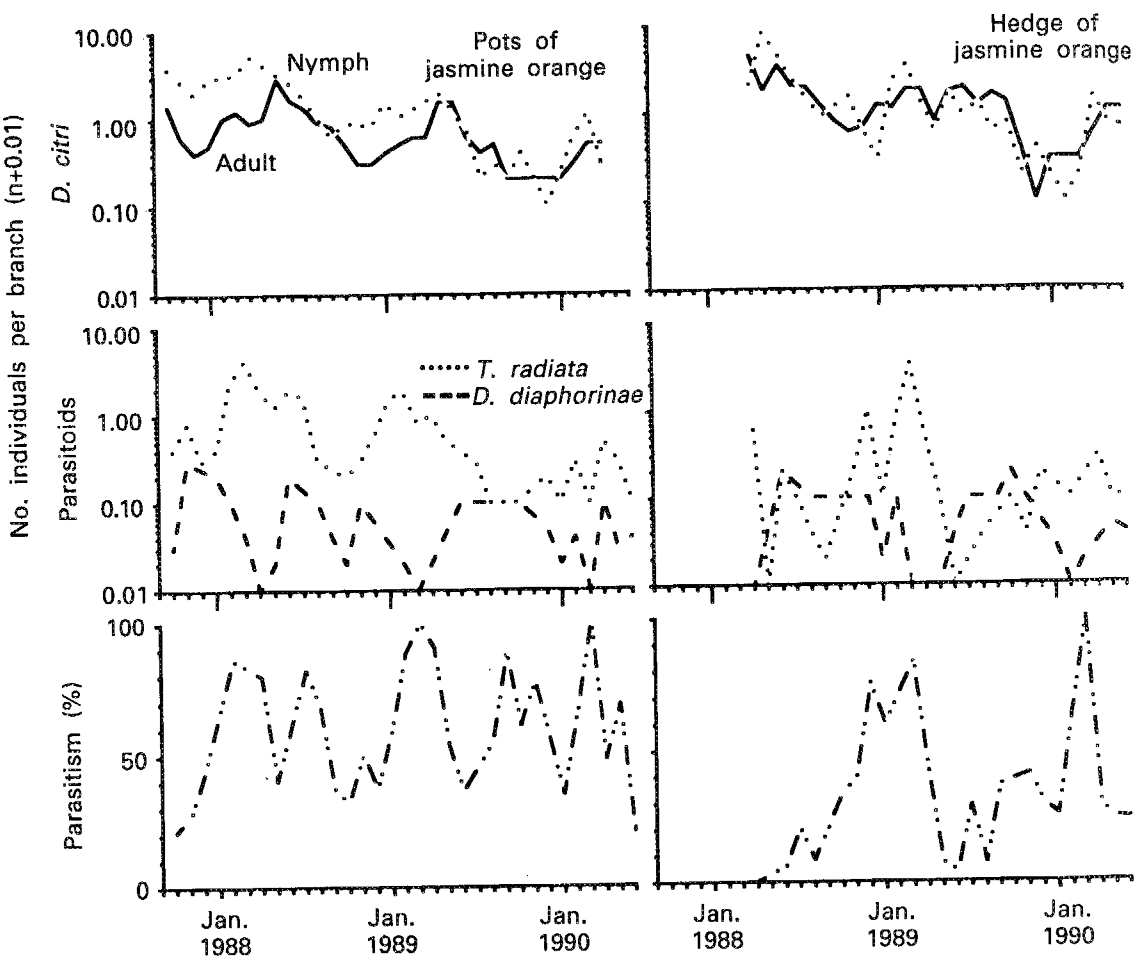

Fig. 3. Parasitism and fluctuations in the population of *Diaphorina citri* and its parasitoids in a stable habitat of jasmine orange *(Murraya paniculata)* at Wufeng, Taichung.

The Efficacy of *T. radiata* and *D. diaphorinae* in a Stable Habitat of *M. paniculata*

T. radiata and *D. diaphorinae* kept *D. citri* at 0 to 0.7 adults per 10 cm branch on jasmine oranges where frequent large-scale pruning and sprayed insecticides were not used. The sites were at Chenchinghu and the old campus of National Ping-Tung Institute of Agriculture (Fig. 4). The average number of mummies of *T. radiata* and *D. diaphorinae* found was 0 to 0.2 and 0 to 0.3, respectively (Fig. 4). The results showed that jasmine orange should not be pruned frequently, to avoid the emergence of too many flushes to harbor psyllids in a fairly stable habitat. Populations of *D. citri* will then be stable due to the parasitism of both parasitoids (Chien *et al.* 1991a).

Influence of Pruning and Insecticide on the Efficacy of Parasitoids in an Unstable Habitat of *M. paniculata*

Jasmine orange trees were pruned every 3 to 4 months at Tienwei, Tashu, the Kaohsiung District Agricultural Improvement Station and Chaochou, and insecticide was sprayed at Tienwei. The *D. citri* and parasitoid populations were affected. At Tienwei, Tashu, the Kaohsiung District Agricultural Improvement Station and Chaochou, the psyllid densities climbed to 0.1 to 2.5, 0.1 to 1.0, 0.2 to 1.1 and 0.4 to 3.5 adults per 10 cm branch, respectively. (Fig. 5). The average number of parasitoids was much lower than the average number of psyllids (Fig. 5). These data showed that *D. citri* fluctuate in an unstable habitat. Population density decreased after pruning, but drastically increased after more oviposition sites became available for adults, while the parasitoids could provide only partial control (Chien *et al.* 1991a).

Influence of Discontinuous Host Existence, Insecticidal Spray or Greening-Infected Citrus on the Efficacy of Parasitoids in Citrus Orchards

Controlled Orchard

An 0.5 ha orchard was sprayed with

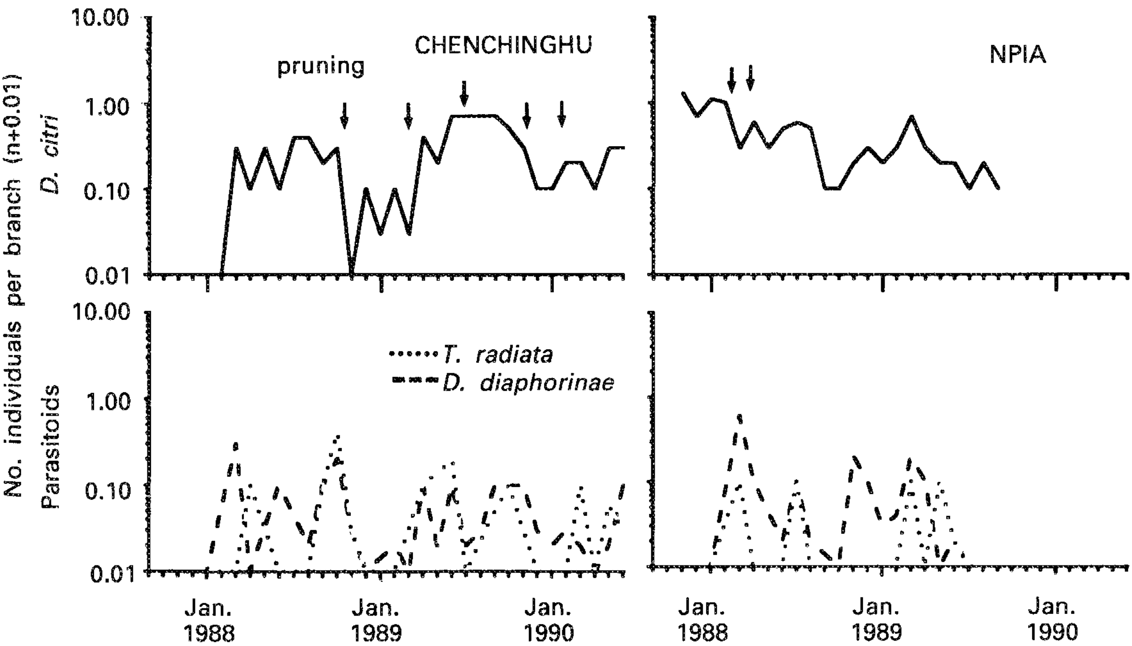

Fig. 4. Population fluctuation of *Diaphorina citri* and its parasitoids under intermediate stable habitat of *Murraya paniculata* at Chenchinghu and the old campus of National Ping-Tung Institute of Agriculture, Pingtung (NPIA).

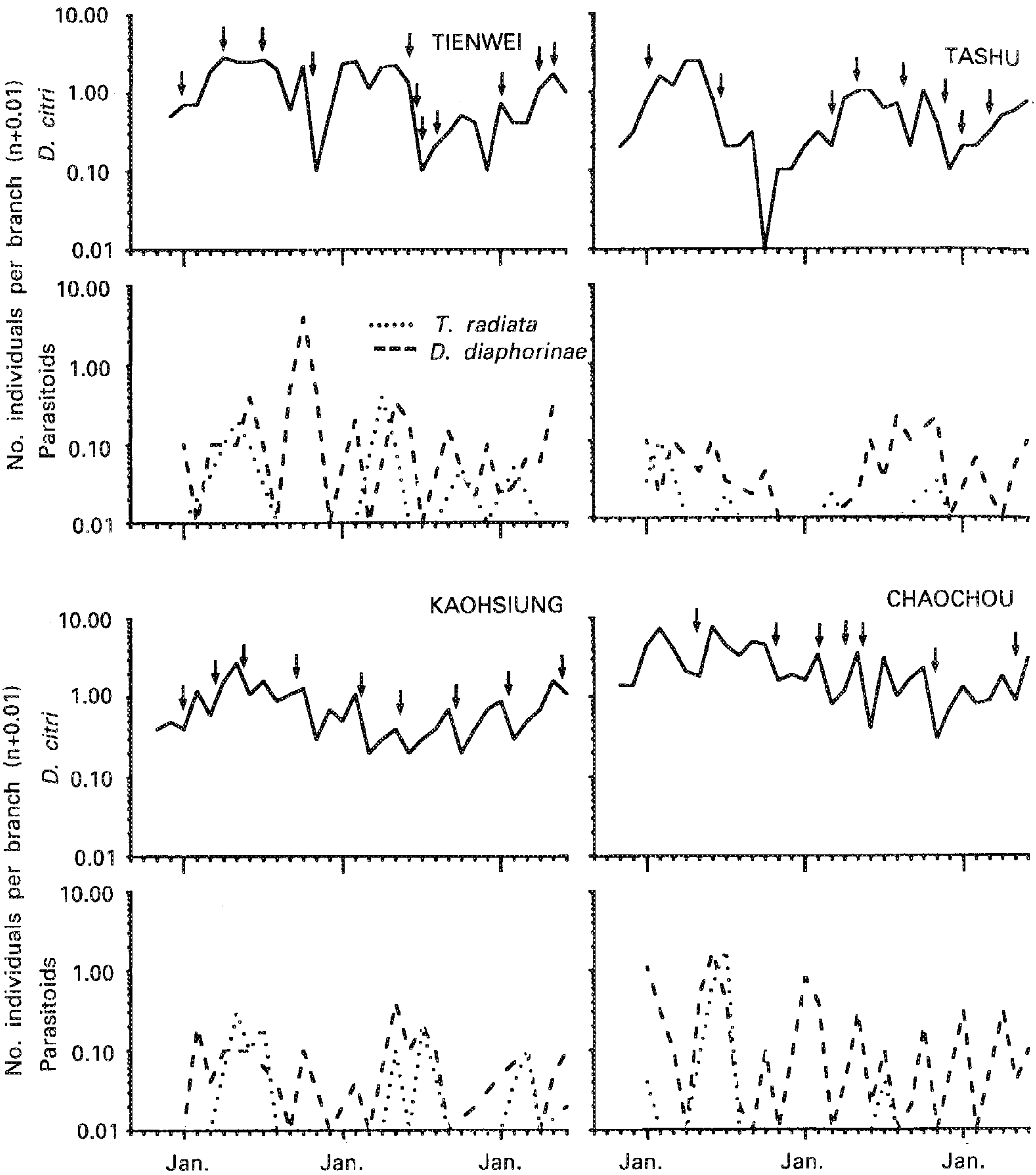

Fig. 5. Fluctuations in the population of *Diaphorina citri* and its parasitoids in an unstable habitat of *Murraya paniculata* at Tienwei, Tashu, the Kaohsiung District Agricultural Improvement Station, and Chaochou.

90% methomyl W.P. 3000x for insect pest control. The number of adult psyllid was nil after spraying, but a few adult psyllids were found during citrus flushing periods without spraying insecticides (0.001 and 0.01 adults per 10 cm branch in February and July, respectively). The average number of adults and nymphs (4th and 5th instar) per 10 cm branch was 0.003 to 0.06 and 0 in March to May, and 0.001 to 0.02 and 0.2 to 0.025 in August to October, respectively. However, the percentage of parasitism was 0.4% and 4.2% in September and October, respectively (Fig. 6). These data showed that methomyl application could give good psyllid control, but the efficacy of the parasitoids was affected

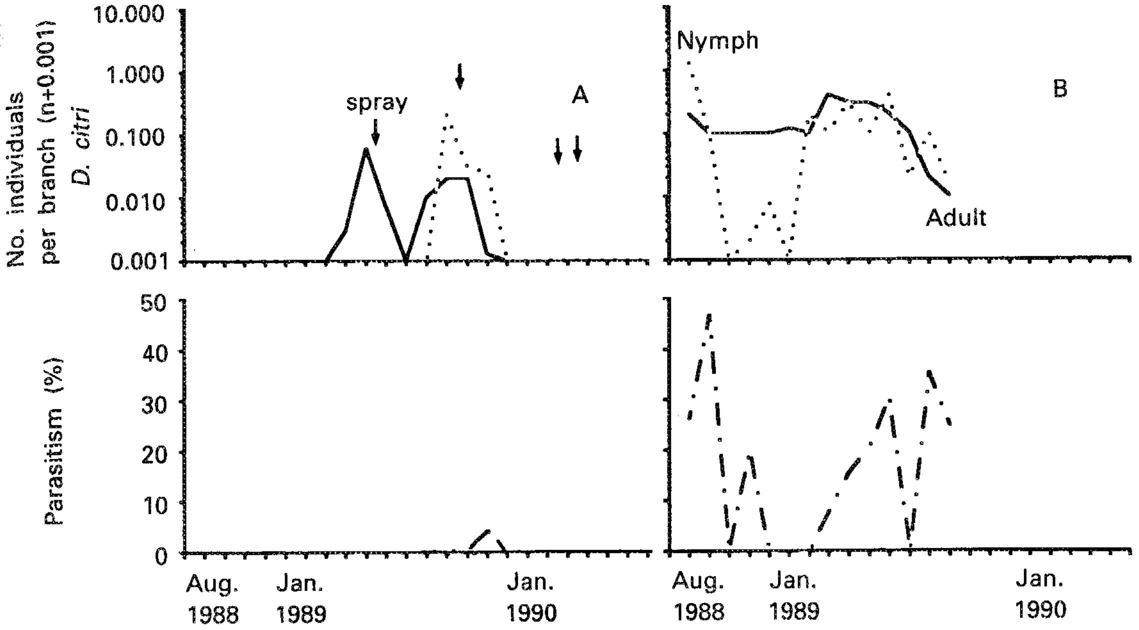

Fig. 6. Fluctuations in the population of *Diaphorina citri* and its parasitoids in controlled (A) and uncontrolled (B) *Citrus sinensis* orchards at Wangeng, Taichung.

by insecticide, the discontinuous presence of the host, and the low density of the psyllids (Chien *et al.* 1991a).

Uncontrolled Orchard

This orchard was 0.55 ha in area and had been abandoned for two years. As the orchard had not been sprayed with insecticide for a long time and was located near a greening-infected field (100 m distant), the citrus plants were gradually infected with greening disease during the experimental period. The leaves and buds of the greening-infected citrus trees attracted adult psyllids for ovipositing. The parasitoids caused 16 - 47% parasitism in April to November in 1988 to 1989, but the average number of adults and nymphs (4th and 5th instar) per 10 cm branch still reached 0.1 - 0.4 and 0.1 - 1.3, respectively (Fig. 6). The experimental citrus trees died and the experiment ended in October 1989 (Chien *et al.* 1991a).

Synchronism of Parasitoids with Hosts

T. radiata and *D. diaphorinae* eggs are formed by autogenous synovigenesis. Female wasps of both species fed with honey can synchronize their oviposition with the existence of the host by oosorption (Chien *et al.* 1991b, Chien 1992). When *T. radiata* was provided daily with 20 5th-instar nymphs of *D. citri* at 25°C after it had been fed with honey and deprived of a host at 15° or 25°C for 20 days, its fecundity was 98 or 156 eggs/female, respectively (Fig. 7), but its progeny survival rate (75 and 76%) and progeny female ratio (0.82 and 0.84) were not affected. When a female wasp was provided daily with 20 5th-instar nymphs of *D. citri* at 25°C after it had been fed with honey and deprived of a host at 15° or 25°C for 40 or 30 days, its fecundity dropped to 23 or 6 eggs/female, respectively (Fig. 7). The female sex ratio of its progeny was 0.27 and 0.6, respectively (Chien 1992).

The fecundity of *D. diaphorinae* was 91 to 22 or 72 to 17 eggs/female when provided daily with 20 4th-instar nymphs of *D. citri* at 25°C after it had been fed with honey and deprived of a host at 15° or 25°C for 30 to 80 or 20 to 60 days, respectively (Fig. 7) (Chien *et al.* unpublished). Even if a female

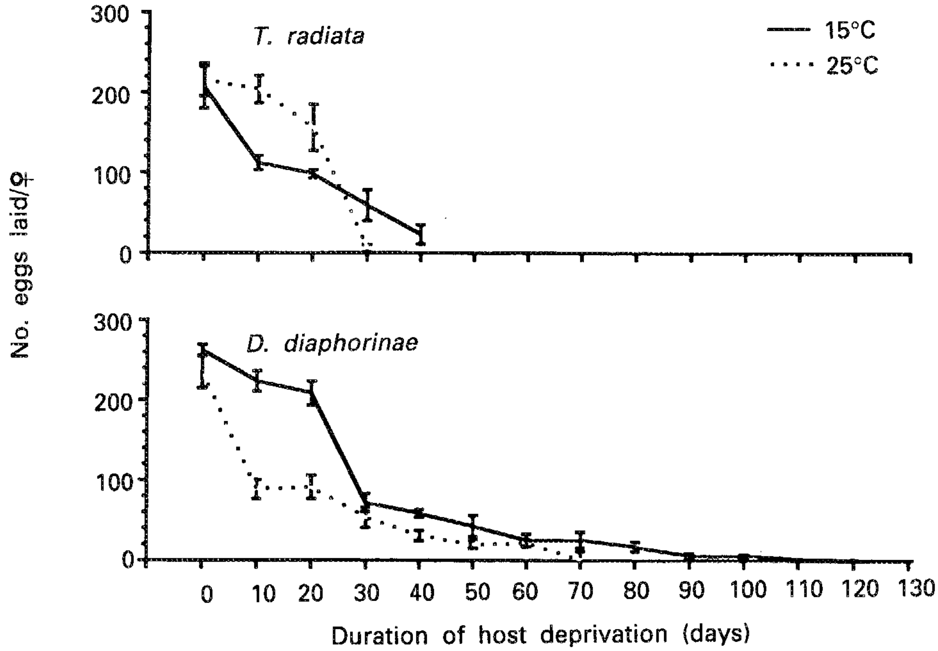

Fig. 7. The fecundity of *Tamarixia radiata* and *Diaphorencyrtus diaphorinae* after various durations of host deprivation at two temperature regimes.

was provided daily with 20 hosts at 25°C after it had been deprived of a host at 15°C for 100 days, its fecundity was still 6.3 eggs/female (Fig. 7) (Chien *et al.* unpublished). Compared with *T. radiata* (20 days), *D. diaphorinae* had greater ability to endure longer periods of host deprivation (20 to 60 days) under 25°C and with honey as food.

Competition and Synergism between *T. radiata* and *D. diaphorinae*

Laboratory Adult Stage Competition

In laboratory tests (3.5 x 20 cm), when the psyllid density was 20 nymphs/twig, 21.8% of the host were parasitized by both *T. radiata* and *D. diaphorinae*. When the host density increased to 40 or 60 nymphs/twig, their interspecific competition ratio decreased to 6.6% or 4.9% (Table 2) (Chien *et al.* unpublished).

The intraspecific competition was stronger in *D. diaphorinae* than in *T. radiata* when the host density was 20 nymphs/twig; 10.4% or 23.1% of the psyllids were simultaneously fed and parasitized and superparasitized by *T. radiata* or *D. diaphorinae*, respectively. When host density increased to 40 or 60 nymphs/twig, their intraspecific competition ratio decreased to 1.7 - 2.0% by *T. radiata,* and 7.4 - 8.7%, by *D. diaphorinae* (Table 2) (Chien *et al.* unpublished).

Laboratory Larval Stage Competition

When both of these two wasps chose the same host for egg deposition, we found that even if the *D. diaphorinae* eggs were laid six days earlier than the *T. radiata* eggs, *T. radiata* was always the wasp which successfully developed to adulthood. This phenomenon was believed to be caused by *T. radiata's* shorter larval stage, although both wasps have the same 2 day egg stage. Accordingly, the 1st and 2nd instar stage of *T. radiata* was 1 and 1 days, while that of *D. diaphorinae* was 4 and 2 days (Chien 1992).

Field Competition and Synergism

In the Taichung area, *T. radiata* (94.6%) was predominant over *D. diaphorinae* (5.4%).

Table 2. Oviposition competition between *Tamarixia radiata* and *Diaphorencyrtus diaphorinae* at different densities of *Diaphorina citri* in the laboratory[1].

Host density 4th:5th (1:1)	n	No. eggs laid[2] T	No. eggs laid[2] D	% Intraspecific competition[2] (S+C) T	% Intraspecific competition[2] (S+C) D	% Interspecific competition[2] T+D
20	20	11.0 ±0.5Aa	11.4±1.4Aa	10.4± 2.7Ba	23.1± 4.0Aa	21.8± 2.2a
40	10	8.2 ±1.1Aa	7.3±1.1Aa	1.7± 1.1Ab	7.4± 3.0Ab	6.6± 2.5b
60	7	10.0 ±0.8Aa	1.6±2.8Aa	2.0± 2.0Aab	8.7± 4.8Ab	4.9± 2.0b

Means (x ± SEM) in the same row followed by the same uppercase letter are not significantly different at 5% level by *t* test. Those in the same column followed by the same lowercase letter are not significantly different at 5% level by LSD.

1. One 4-day old female wasp of each species per treatment in a test tube, 3.5x20 cm from 9 a.m. to 1 p.m. under 25°C, 14:10 (L:D) and 100% RH.
2. T: *Tamarixia radiata*; D: *Diaphorencyrtus diaphorinae*; S: % Superparasitism; C: % Simultaneously fed and parasitized.

Due to differential seasonal occurrences of the two wasps, no obvious interspecific competition was observed during the prevailing period. In situations where they occurred simultaneously, they had a synergistic control effect against the psyllid. For example, at the Wufeng sites with potted jasmine orange and a hedge of jasmine orange, the percentage of parasitism by *T. radiata* was 80 - 99.7% and 58 - 95% from February to April, while *D. diaphorinae* rarely occurred. For the rest of the year, the total percentage of parasitism (32 - 80%) was much higher than when *D. diaphorinae* occurred alone (9.6 - 57%) before the importation of *T. radiata* (Fig. 8).

In southern Taiwan, the densities of *T. radiata* and *D. diaphorinae* were approximately the same except at Chaochou, where the density was significantly affected by a disturbed habitat (Figs. 4 and 5).

Therefore, at this stage of testing, although there appeared to be some interspecies competition between *T. radiata* and *D. diaphorinae* after *T. radiata* was imported, their synergistic effects were stronger, leading to an increase in the total suppression of *C. citri* (Chien *et al.* 1991a).

Hyperparasitoids of D. diaphorinae and T. radiata

During our survey of the jasmine orange hedges in Taiwan, carried out from May 1985 to June 1990, we collected a total of 20,749 psyllid mummies parasitized by *D. diaphorinae*. About 40.6% of these were found to be parasitized by 11 species of hyperparasitoid (Fig. 2), with the dominant species being *Pachyneuron condolor* Forester, *Chartocerus walkeri* Hayat, *Syrphophagus taiwanus* Hayat & Lin, and *Marietta leopardina* Motschulsky (Chien *et al.* 1991a).

From September 1986 to June 1990, 16,646 psyllid mummies parasitized by *T. radiata* were collected. In 1986, when the population of *T. radiata* was just established, 1.1% of the wasps were hyperparasitized by 6 species of hyperparasitoids (Fig. 2). In 1990, the hyperparasitoids increased to 7 species and the percentage of hyperparasitism increased to 5.6% (Fig. 2). However, the efficiency of *T. radiata* against the psyllid was not affected (Fig. 3). The dominant species were *M. leopardina*, *P. concolor* and *Encarsia* sp. near Shafei (Chien *et al.* 1991a).

INFLUENCE OF DISTURBED HABITAT ON THE POPULATION FLUCTUATION OF *D. CITRI* AND ITS PARASITOIDS

Pruning of Jasmine Orange

Pruning of jasmine orange at a frequency of once every three or four months significantly influences populations of *D. citri* and its parasitoids. *T. radiata* was the parasitoid most affected, followed by *D.*

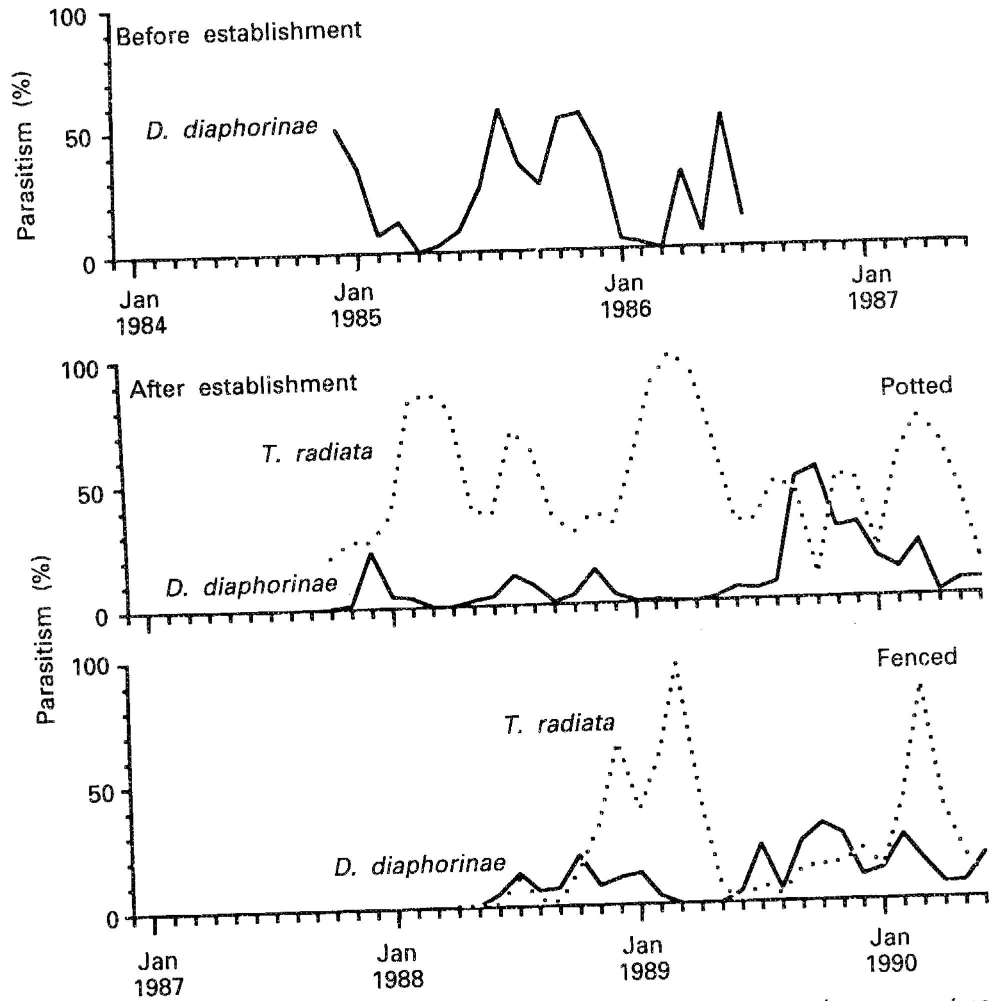

Fig. 8. Competition between *Tamarixia radiata* and *Diaphorencyrtus diaphorinae* after *Tamarixia radiata* was established in a stable habitat of *Murraya paniculata* at Wufeng, Taichung.

diaphorinae and *D. citri*. The reasons for this are considered to be:

Longevity

According to Tang and Su (1984), the longevity of *D. citri* averaged 93.3 days at 25°C. After the pruning of the jasmine orange plants, the adults of *D. citri* might stay and damage old leaves for three or four months (Lin *et al.* 1973), meaning that their longevity was scarcely influenced by pruning. On the other hand, the parasitoids feed on the honey dew excreted by *D. citri* nymphs which damage the twigs after pruning (Chien *et al.* 1991b). In temperatures under 25°C and at times of food shortage, the longevity of female *D. diaphorinae* and *T. radiata* averaged 1.4 and 1.0 days, respectively. The intake of water prolonged the life of both parasitoids by about one day. If wasp adults were provided with honey, their longevity increased to 60.7 and 22.5 days, respectively (Chien 1992). Accordingly, in the pruned habitat, the existence of another food source for the wasps became an influential factor in determining longevity. *T. radiata* was more seriously affected by pruning than *D. diaphorinae*.

Behavior of Oviposition

D. citri only oviposits on the buds of host plants. Although the pruning of jasmine orange plants limited the number of psyllid eggs and nymphs and caused the emigration of the majority of adults, it caused a later flushing of the plants, providing abundant oviposition sites for adults. Psyllid adults could synchronize their reproduction with the emergence of new flushes on the pruned jasmine oranges by staying on mature leaves as long as 14 to 21 days in summer and 60 days in winter without laying eggs. Their ovipositing then occurred on a flushing tree. The 2nd and 5th instar psyllid nymphs are suitable oviposition targets for *D. diaphorinae* and *T. radiata*, respectively. The psyllid grew to those stages 6 and 12 days after egg laying occurred at 25°C (Chien *et al.* 1991a, 1991b, Chu and Chien 1991). When the eggs were laid on psyllid nymphs of the 4th instar, the female ratio of *T. radiata* decreased from 0.76 to 0.16, its female progeny size dropped from 1.12 x 0.36 to 0.91 x 0.3 mm, longevity dropped from 18.0 to 14.4 days and fecundity dropped from 215 to 120 eggs/female (Chien *et al.* 1991b, Chu and Chien 1991). The frequent pruning of jasmine oranges trees caused less synchronization between host occurrence and the oviposition of parasitoids. Accordingly, an undisturbed habitat is an important factor for the oviposition of parasitoids, especially *T. radiata*.

Reproduction Type

The type of parthenogenesis of *D. diaphorinae* is thelytoky (Tang and Huang 1991) and *T. radiata* is arrhenotoky (Chien *et al.* 1991b, Chu and Chien 1991). Both wasps could regulate their oviposition time by oosorption (Chien *et al.* 1991b, Chien 1992). According to laboratory tests, the synchronism of *T. radiata* to its host insect was more closely related than that of *D. diaphorinae* under conditions of 25°C, with honey as food and host deprivation of less than 20 days. The synchronism of *D. diaphorinae* was better when host deprivation was 30 to 60 days at 25°C. The population growth of *T. radiata* was influenced more significantly than that of *D. diaphorinae* when the habitat was disturbed or its host density was low.

Application of Insecticides

The psyllid is quite sensitive to chemicals. Most insecticides used to control citrus insects have a marked influence on the psyllid. Therefore, Lin *et al.* (1973) suggested that insecticides be used during the flushing period to control *Aphis citricola* van der Goot, *Toxoptera citricidus* (Kirkaldy), and *Phyllocnistis citrella* Stainton, as well as psyllids. The results of our experiment showed that parasitoid activity on citrus was decreased by the spraying of insecticides (Fig. 6).

THE USE OF PARASITOIDS IN AN IPM SYSTEM TO CONTROL *D. CITRI* AND GREENING DISEASE

The number of psyllids on a tree was closely related to the number of buds, which varied with the variety and age of the trees, the irrigation and fertilization situation, and the mechanical stimulation of pruning and typhoons (Lin *et al.* 1973). Under natural conditions, the spread of greening disease depends on the amount of the greening disease pathogen in the environment and the psyllid population density (Aubert 1987). Psyllids have a tendency to aggregate (Wang 1981, Chien 1992), and when the host plant environment is adequate for psyllid survival, the adults do not usually emigrate and disperse. When host plant conditions are unfavorable, the adults disperse actively by air currents and immigrate to a newly flushed point on another host plant (Samways 1987). The spread of greening disease has also shown an aggregation tendency (Gottwald *et al.* 1989).

In Taiwan, the average transmission rate was only 1.3% in greenhouses (Huang *et al.* 1984). Huang *et al.* (1990) proved that greening disease was transmitted rapidly when healthy seedlings were intercropped with diseased seedlings in fields. When 394 adult psyllids were released, 57% of the healthy seedlings were infected after 6 months. This proportion increased to 73% after one year, and 100% after two years. When 60 healthy Ponkan seedlings were planted 10 m away from the greening-infected field, none were infected after intensive insecticide spraying (one spray of lannate, malathion or furadan/10 days) for a 2-year period. These results indicated that insecticide application effectively prevented the spread of the disease. Chemical control is also a major method of controlling psyllids in citrus orchards in Reunion and Mainland China (Aubert and Quilici 1984, Qian 1989, Ke 1991, Xu *et al.* 1991).

Jasmine oranges are usually grown as hedge plants, and they are also the major host plants of *D. citri*. These plants do not harbor the greening pathogen (Gottwald *et al.* 1989). If the parasitoids can depress the population density of psyllid on jasmine orange to a low level, thereby limiting the chance of psyllid immigration into citrus orchards, the biocontrol of *D. citri* on jasmine orange should be considered as practical. The threshold density for the occurrence of psyllid dispersal on jasmine orange has not yet been estimated. However, the results of our experiments have proved that parasitic wasps have the ability to depress the psyllid population, and that psyllids will not obviously disperse on jasmine orange when conditions are stable. To keep the jasmine orange in a stable situation, large-scale pruning and insecticide spraying should be avoided. They will then provide a good habitat for both introduced and native wasps, and will lower the density of psyllids.

Use of parasitoids is not practical in orchards because: i) a single psyllid with the pathogen can transmit the greening disease (Xu *et al.* 1990), ii) the application of insecticides is necessary for citrus cultivation, iii) the psyllid is quite sensitive to chemicals, and iv) the normal activities of parasitoids are seriously restricted by new citrus tree buds. As these buds are not in continuous existence, the following manipulations are recognized to be important. In citrus orchards, healthy seedlings of selected varieties should be grown in disease-free areas (at least 1 to 3 km away from the disease-infected field) (Ke 1991, Xu *et al.* 1991), and infected stems and branches should be cut or the whole diseased tree dug out to eliminate the chance of further infection. The use of proper cultivation systems would cause the trees to flush uniformly. This would in turn increase the effect of insecticide applied to control psyllids, aphids and leaf miners. To decrease the source of psyllids, the elimination of jasmine oranges near citrus orchards is also very important.

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