Occurrence of the Asian Citrus Psylla and its Parasitic Natural Enemies in the Ryukyu Archipelago, Japan

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Abstract

A survey of the seasonal occurrence of Asian citrus psylla, *Diaphorina citri*, which is the vector of Asian citrus greening disease, and of its parasitic natural enemies, was conducted at six sites containing *Murraya paniculata* on Ishigaki Island (24°19'-36'N and 124°4'-20'E, the southernmost part of the Ryukyu Archipelago), Okinawa, Japan. The population of adult psylla increased in early spring when newly sprouted shoots of *M. paniculata* were abundant, but the trends differed from place to place even on the same island. Two species of parasitic wasps were discovered. One was an unidentified encyrtid and another was the eulophid *Tamarixia radiata*. The populations of the encyrtid were rather stable and low, but populations of *T. radiata* fluctuated considerably.

A survey of parasitic natural enemies of Asian citrus psylla was also conducted in other areas of the Ryukyu Archipelago: Amami Island (28°5'-30'N and 129°0'-40'E, the northernmost area inhabited by Asian citrus psylla); Okinawa Island (26°4'-53'N and 127°37-128°20'E); Kume Island (26°17'-23'N and 126°42'-50'E); Miyako Island (24°42'-55'N and 125°15'-29'E); and Yonaguni Island (24°26'-28'N and 122°56'-123°3'E). On Amami Island, only the Asian citrus psylla was detected. On Okinawa, Miyako and Yonaguni Islands, the Asian citrus psylla and the same two parasitoids detected on Ishigaki Island were detected. On Kume Island, the Asian citrus psylla and the encyrtid parasitoids were found. *T. radiata* is an introduced natural enemy against Asian citrus psylla in Taiwan, and it is unlikely that this parasitoid occurs naturally in Japan.

INTRODUCTION

Citrus greening disease is one of the most important diseases of *Citrus* fruits in tropical and subtropical Asia. The disease is caused by the Asian strain of greening organism (GO), which is a bacterium-like organism (BLO) restricted to the sieve tubes of host plants. Asian citrus psylla, *Diaphorina citri* is a vector of the Asian strain of GO. *D. citri* prefers *Murraya paniculata* as a host plant rather than various cultivated *Citrus* species (Aubert, 1987), but infection of GO on *M. paniculata* has not yet been reported.

In Japan, *Citrus* fruits are produced in the southwestern part of Honshu, Shikoku, Kyushu, and the Southwestern Islands including the Ryukyu Archipelago. The occurrence of Asian citrus greening disease in Japan was not reported until 1988 at Iriomote Island (Miyakawa and Tsuno, 1989). Greening disease was eradicated in 1989, but it was discovered again on Iriomote Island in 1993 and on Okinawa Island in 1994 (Toguchi and Kawano, 1997). Moreover, its distribution has expanded to almost all islands between Yonaguni Island and Okinawa Island (Fig. 1). *D. citri* is known to inhabit the islands between Yonaguni Island and Amami Island, however, greening disease has not been detected on more northeastern islands than Okinawa Island (Fig. 1).

Since GO cannot be excluded from plant tissue, it must be controlled by removing infected plants and/or controlling the vector insect, *D. citri*. Recently, methods have been

developed to detect GO by PCR, making diagnosis of the disease easy. However, the removal of infected plants is very difficult because of the poor understanding of GO by farmers. Under such circumstances, the control of the vector insects becomes more important, and an understanding of the ecological aspects of the vector is necessary for the control of GO.

Several organophosphorus insecticides, including fenitrothion (MEP) and methidathion (DMTP), will control *D. citri*. However, natural enemies of *D. citri* may be also sensitive to these insecticides. *D. citri* inhabit *Citrus* orchards and *M. paniculata* hedges, so insecticide spraying in *Citrus* orchards for the control against *D. citri* may not be efficient. Two species of parasitoids of *D. citri*, *i.e.* an encyrtid *Diaphorencyrtus diaphorinae* (=*D. aligarhensis*) and an eulophid *Tamarixia radiata*, are known (Aubert, 1987). An introduction of *T. radiata* to Taiwan from Reunion Island did not seem to be successful (Chien et al., 1989). However, control of *D. citri* by the introduction of *T. radiata* from Punjab to Reunion Island was successful, possibly because of the absence of hyperparasitoids (Aubert and Quilici, 1983).

Until the invasion of GO into Japan, the importance of *D. citri* as a pest of *Citrus* had a low priority in Japan. Therefore the seasonal occurrence and other ecological aspects of *D. citri* in Japan had not been studied. Since the use of natural enemies has potential for the control against *D. citri*, we conducted a survey of the fauna and the distributions of the parasitoids of *D. citri* in the Ryukyu Archipelago. We also studied the seasonal occurrences of the parasitoids of *D. citri* on Ishigaki Island, which is located in the southernmost part of the Ryukyu Archipelago.

MATERIALS AND METHODS

Survey of Seasonal Occurrence of *D. citri* and its Parasitoids in Ishigaki Island

We censused the populations of *D. citri* and its parasitoids in two natural areas (site A and F, see Fig. 2) and four artificial hedges (site B, C, D and E, see Fig. 2) of *M. paniculata* on Ishigaki Island. Populations of *D. citri* were sampled by the number of individuals captured in yellow-colored sticky traps (10 cm wide and 25 cm long, both sided). These traps were hung on twigs of *M. paniculata* for 1 week at monthly intervals for months. Nymphs of *D. citri* were collected at the six sites every month and reared in the laboratory. The emerged parasitoids were identified and recorded, and parasitism rate was calculated as the proportion of the emerged number of natural enemies by the collected number of *D. citri* nymphs.

Survey of Parasitoids of *D. citri* in the Ryukyu Archipelago

Nymphs of *D. citri* were collected at several *M. paniculata* sites on Amami, Okinawa, Kume, Miyako and Yonaguni Islands (see Fig. 1). The collected nymphs were reared in the laboratory and emerged parasitic natural enemies from the nymphs were counted and identified.

RESULTS

Occurrence of *D. citri* and its Parasitoids in Ishigaki Island

The seasonal occurrence of *D. citri* captured in yellow-colored sticky traps at six survey sites is shown in Fig. 3. Trends in population changes at each site were different, but populations in spring (February to April) seemed to be relatively abundant or increasing at all sites. The number of *D. citri* trapped in natural *M. paniculata* vegetation (site A and F) sometimes dropped to zero, but those in artificial hedges (site B, C, D and E) were seldom zero. Nymphs of *D. citri* were seen only on newly sprouted shoots of the host plants. The newly sprouted shoots of *M. paniculata* were observed year-round in artificial hedges, but were most abundant in spring.

Parasitism by *Tamarixia radiata* was relatively high in spring (March to May), but the trends at each site were different (Fig. 4). Parasitism by the encyrtid was fairly low in

every site throughout the study period (Fig. 5), except site F in November 1999, when only one *D. citri* nymph was sampled. The ratio of the number of *T. radiata* to the number of the encyrtid was about 8:1.

Fauna of Parasitic Natural Enemies on *D. citri* in the Ryukyu Archipelago

The parasitoids of *D. citri* on the islands of the Ryukyu Archipelago are listed in Table 1. Two species of primary parasitoids but no hyperparasitoids were found in the area. No parasitoids were found on Amami Island, which is the northern limit of the distribution of *D. citri*. The encyrtid was discovered on all other islands surveryed. However, the rate of parasitism by the encyrtid was fairly low on all islands. *T. radiata* was found in the southern part of the study area, except for one individual found in Itoman, Okinawa Island. The rate of parasitism by *T. radiata* was relatively high in the southern part of the study area, especially on Yonaguni Island, which is about 120 km from Taiwan.

DISCUSSION

The population increase of *D. citri* in spring seemed to be related to the amount of newly sprouted shoots of *M. paniculata*. However, population trends in artificial hedges were not so obvious, possibly because new shoots sprouted after trimming of the twigs.

T. radiata is an imported natural enemy to Taiwan (Chiu and Chien, 1989), and although no survey on natural enemies of *D. citri* had been conducted before our study, it would seem that *T. radiata* has spread to Ishigaki Island and surrounding islands from Taiwan. It is unlikely that *T. radiata* is indigenous to the Ryukyu Archipelago, because it had to be introduced from Taiwan, which is only 250 km from Ishigaki Island and about 120 km from Yonaguni Island.

Although the rate of parasitism by *T. radiata* was higher on the islands near Taiwan (Table 1), it was collected also on Okinawa Island. This may indicate that *T. radiata* can establish also in Okinawa Island. The rate of parasitism by *T. radiata* was relatively high, but unstable. The rate fluctuated considerably and seemed to increase when populations of *D. citri* were high. In contrast, the rate of parasitism by the encyrtid, which may be *Diaphorencyrtus diaphorinae*, was always low (Aubert, 1987).

Although it is unknown whether invasion by *T. radiata* to the Ryukyu Archipelago was natural or accidental, it appears to be established at least in the southern part of the Ryukyu Archipelago (Miyako, Ishigaki and Yonaguni Islands). Because it is already established, it should be further evaluated as a biological control agent against *D. citri*.

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Tables

Table 1. Parasitism on *D. citri* larvae collected on several islands of the Ryukyu Archipelago (excluding Ishigaki Island).

Collection Site	Season	Collected No. *D. citri larvae*	Emerged No. Parasitic Wasps	
			T. radiata	Unidentified encyrtid
Amami Island	May 1999	44	0	0
Okinawa Island				
Itoman	Jan. 2000	42	1	0
Gushikami	Jan. 2000	102	0	0
Shuri	Jan. 2000	62	0	5
Nakijin	Jan. 2000	35	0	0
Urasoe	Mar. 2000	75	0	0
Kume Island	Mar. 2000	78	0	4
Miyako Island	Apr. 2000	419	23	0*
Yonaguni Island	Nov. 1999	43	14	1

*An adult of the encyrtid was observed when collecting *D. citri* larvae

Figures

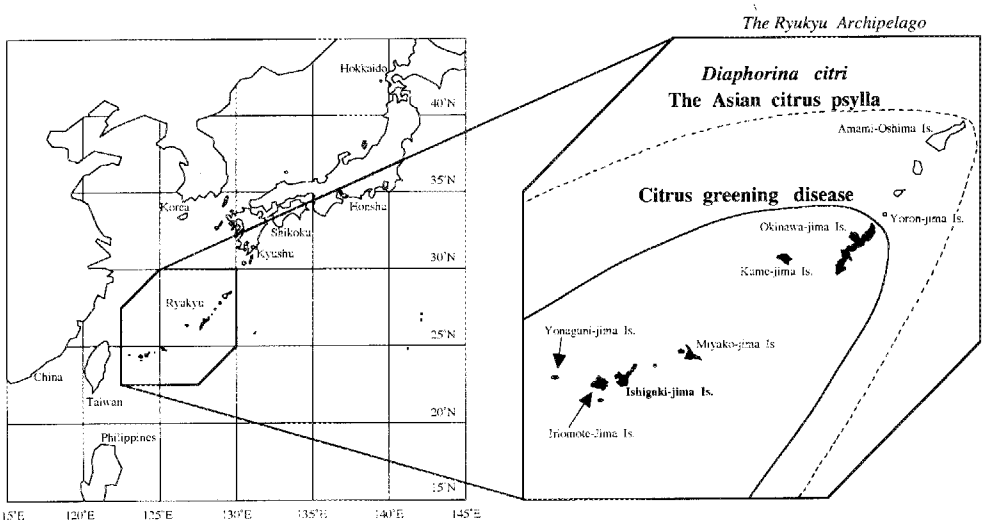

Fig. 1. Distribution of the Asian citrus greening disease and the Asian citrus psylla in the Ryukyu Archipelago.

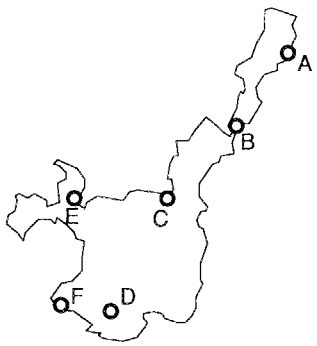

Fig. 2. Sites of population census of *D. citri* and its parasitoids in Ishigaki Island.
A: Yasura; B: Ibaruma; C: Ohta; D: Tonoshiro; E: Kabira; F: Fusaki.

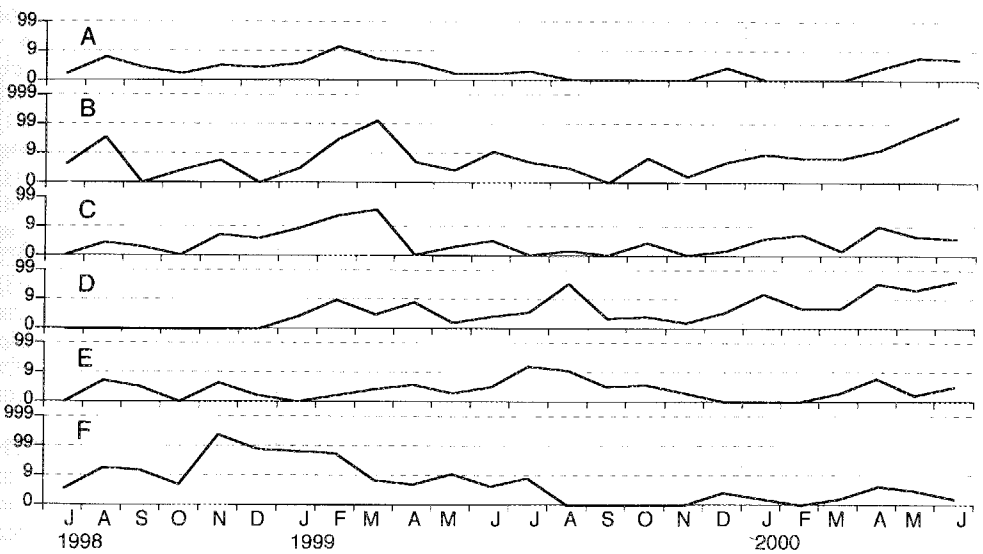

Fig. 3. Changes in the trap catches of the citrus psylla in yellow-colored sticky traps. Values were presented in the logarithmic scale with the captured number per seven days for each month.

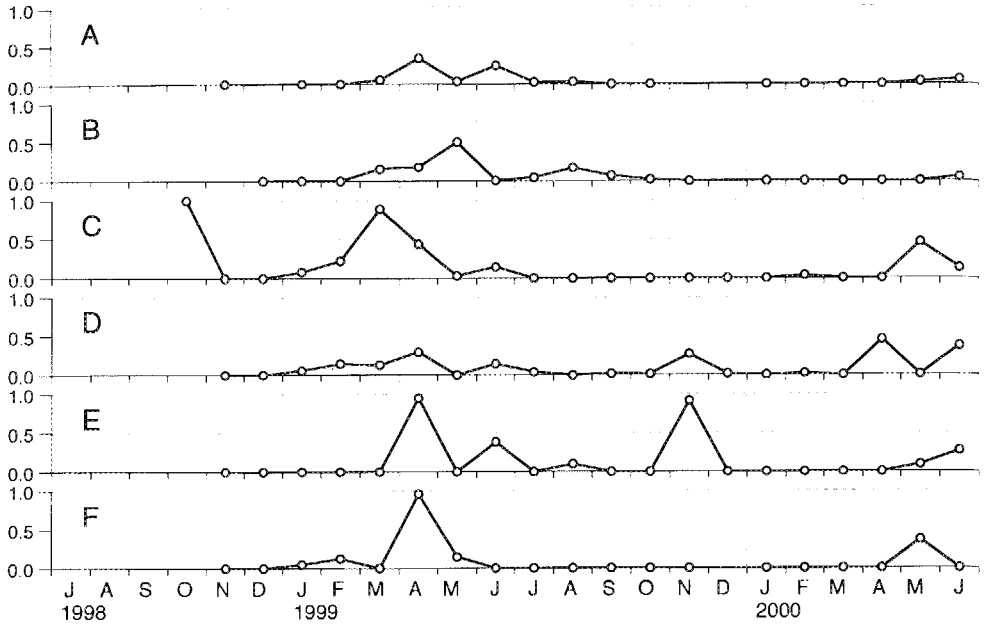

Fig. 4. Changes in the ratio of parasitism by the eurphid wasp, *Tamarixia radiata* on the *citrus psylla* nymphs.

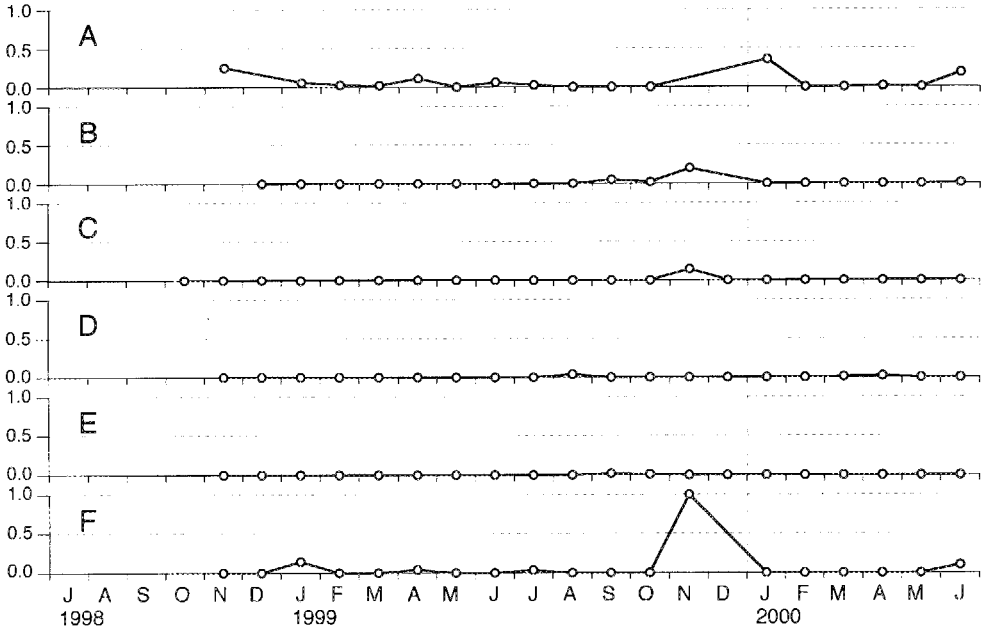

Fig. 5. Changes in the ratio of parasitism by the encyrtid wasp on the *citrus psylla* nymphs.