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Eradication of the Melon Fly, *Bactrocera cucurbitae* Coquillett, by Mass Release of Sterile Flies in Okinawa Prefecture, Japan

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Abstract

In 1972, MAFF, Japan and the Okinawa Prefectural Government initiated an experimental eradication project of the melon fly from Kume Island, Okinawa Prefecture, Japan using the sterile insect technique (SIT). Following the successful eradication on Kume Island in 1978, large scale SIT was started to eradicate the melon fly on the 3 groups of islands, Miyako, Okinawa and Yaeyama of Okinawa Prefecture, Japan in 1984, 1986 and 1989, and eradication was achieved in 1987, 1990 and 1993, respectively. For the successful eradication on Miyako, Okinawa and Yaeyama groups of islands, about 6,340, 30,940 and 15,440 million sterile melon files were released, respectively.

Discipline: insect pest
Additional key words: male annihilation, SIT (sterile insect technique)

Introduction

The melon fly (*Bactrocera cucurbitae*) not only causes serious damage to cucurbit crops but also infests various fruits and vegetables such as tomato, papaya and mango. Because of its occurrence in the Southwestern Islands of Japan, transportation of such host crops from the islands had been strictly prohibited by Japanese plant protection law. Some kinds of crops could be transported after fumigation, which requires extra cost and facilities. Such restriction made it imperative that the melon fly be eradicated from the islands.

In 1972, the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan and the Okinawa Prefectural Government (OPG) initiated an experimental eradication project of the melon fly from Kume Island, by using the sterile insect technique (SIT). The project which was the first attempt to use this technique in Japan, enabled to develop basic data relating to SIT for eradicating the melon fly throughout the Southwestern Islands. Following the successful eradication on Kume Island in 1978, large scale SIT was initiated to eradicate the melon fly on Miyako, Okinawa and Yaeyama groups of islands in 1984, 1986 and 1989, respectively, and the eradication was achieved in 1987, 1990 and 1993, respectively. For the successful eradication on Miyako, Okinawa and Yaeyama groups of islands, about 6,340, 30,940 and 15,440 million sterile flies were released, respectively. Fig. 1 shows the years of introduction and eradication of the melon fly in each group of the Southwestern Islands in Japan. The results obtained and problems encountered in the project are reviewed.

Experimental eradication project on Kume Island

In 1972, an experimental eradication project of the melon fly using SIT was initiated on Kume

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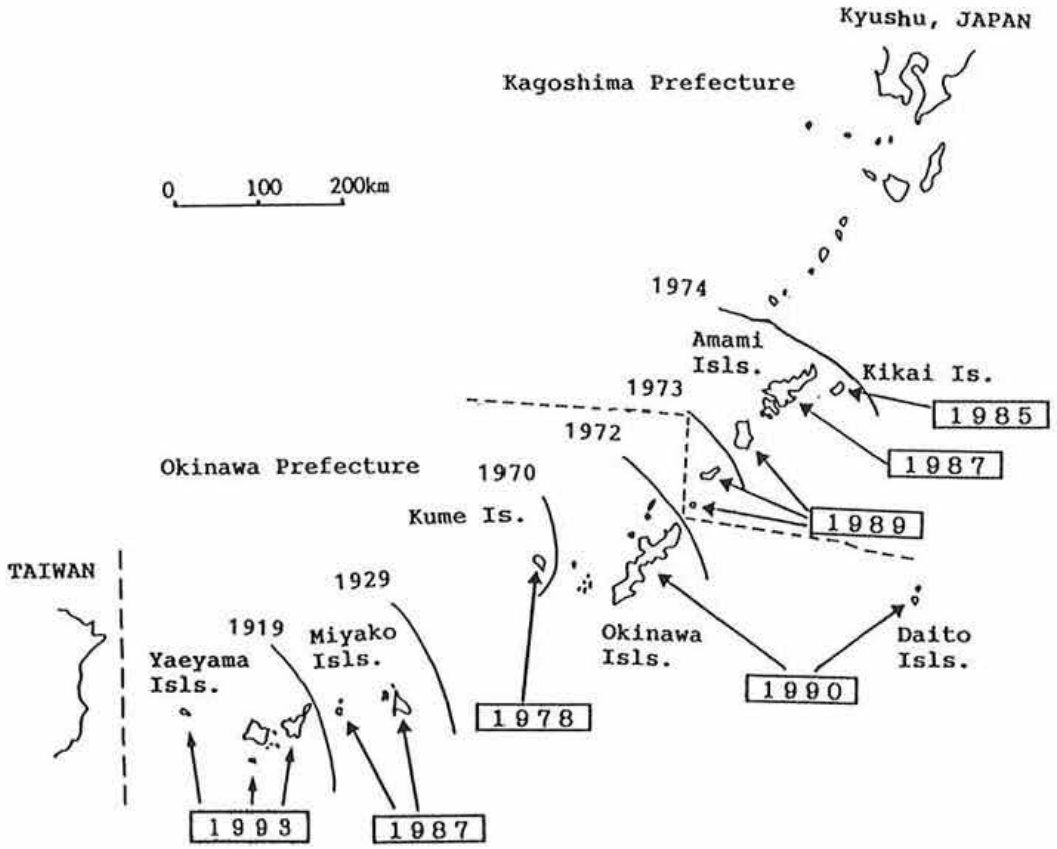

Fig. 1. Introduction and eradication of the melon fly in the Southwestern Islands, Japan
Arabic numerals and those in squares indicate the years of introduction and eradication, respectively. Broken line shows the border of the prefecture and country.

Island (60 km^2). For this project, a mass rearing facility and an irradiation facility were constructed on Ishigaki Island and in Naha, Okinawa Island, respectively.

In this project, basic studies for the development of SIT were carried out, including methods of mass rearing of the melon flies to produce 5 million pupae per week[15], determination of appropriate irradiation dose for sterilization[18] and methods of transportation and release of sterilized pupae. Iwahashi[4] summarized the results obtained in the Kume Island project.

Before starting mass releases of sterile flies, the population density of the wild melon flies on Kume Island was estimated using the mark-recapture method. The number of mature wild males in the peak season on Kume Island was estimated to be about 2.5 million[3]. Meanwhile the production capacity of the mass rearing facility just before the onset of sterile insect releases was only 1–1.5 million which seemed to be insufficient to achieve the eradication.

The first step in the eradication project was the suppression of wild populations using the male annihilation technique. From December 1972 to December 1974, suppressive control of the melon fly was carried out using fiber blocks or cotton ropes impregnated with cue-lure, a male attractant for the melon fly, and BRP, an insecticide, along with poisoned protein hydrolysate, an attractant for fruit flies, by spraying. Possibly due to these treatments, the density of the wild melon fly population just before the onset of mass release was estimated to be about 5% of the peak density[5].

From February 1975, about 1 million sterile flies were released weekly as pupae in buckets distributed on Kume Island. However, the ratio of sterile to normal (wild) flies caught by a monitoring trap (S/N value, hereafter) did not exceed one[6]. The estimated population density of the fly before the release[3] and calculation based on an eradication model[2] indicated that 4 million flies had to be released weekly to achieve eradication rapidly. From September 1975, the number of sterile flies released

Table 1. Yearly schedule of the melon fly eradication project in Okinawa Prefecture, Japan

Year	Items
1980	Construction of the building for mass production (Total capacity enabled to produce 100 million pupae/week)
1981-82	Construction of the equipment for producing 30-50 million pupae/week
1983	Construction of the irradiation facility
1984-86	Release of sterile flies and eradication on Miyako Islands
1986	Adjustment of the equipment to produce 100 million pupae/week
1987-89	Release of sterile flies and eradication on Okinawa Islands
1990-	Release of sterile flies and eradication on Yaeyama Islands

increased to 2 million per week. As a result, an S/N value of 10 was recorded in May 1976. The number of released flies increased to 3.5-4 million per week from May 1976, after which the S/N value exceeded 100, and the percentage of infested host fruits decreased to 0 in August 1976. As the 0 infestation level was maintained for 1 year, it was considered that eradication had been achieved[4].

After successful eradication of the melon fly from Kume Island, MAFF, Japan and OPG began a large scale project aimed at eradicating the melon fly throughout the Okinawa Prefecture with SIT in 1980[7]. The prefecture consists of 3 groups of islands, Okinawa Islands, Miyako Islands and Yaeyama Islands. The large scale project was carried out according to the yearly schedule (Table 1).

Miyako Islands project

As a sub-project of the large scale one, an eradication project was started on Miyako Islands (227 km^2) in 1984.

At first, Kuba et al.[13] estimated the density of male melon flies with a mark-recapture experiment, using Hamada's method, which is a modification of Jackson's positive method[1]. The peak number of male flies on Miyako Islands was estimated to be 34.4 million in July. At that time, the new mass

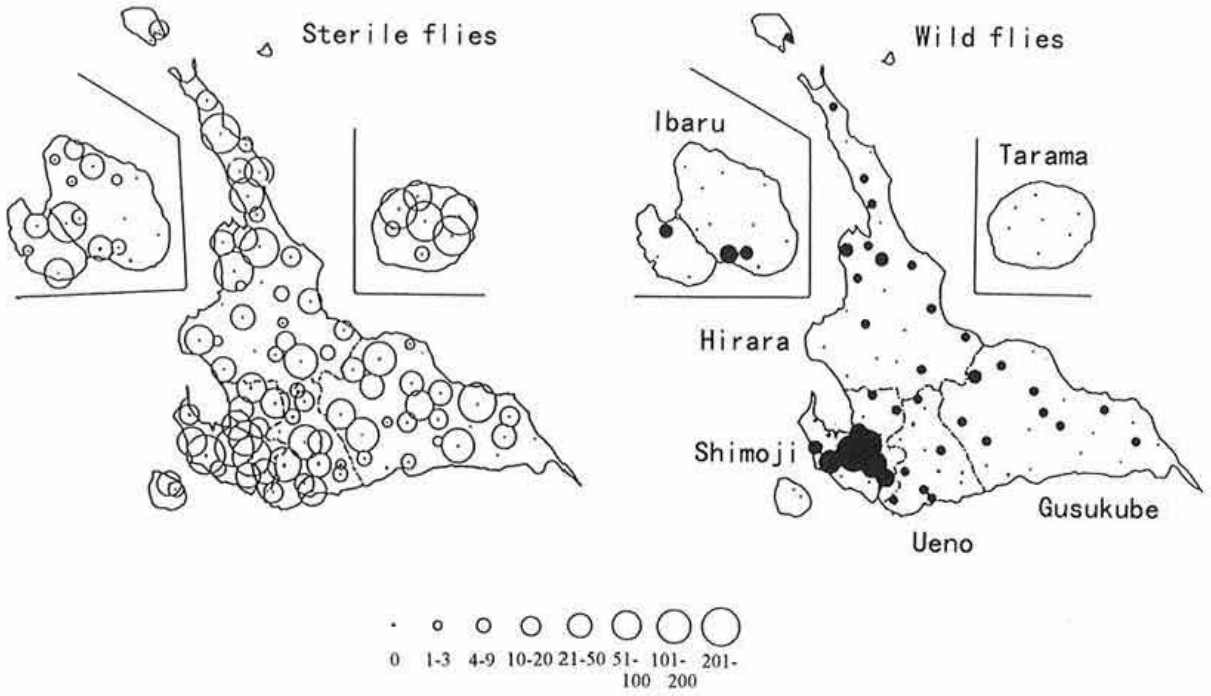

Fig. 2. Distribution and number of sterile and wild melon flies caught by monitoring traps on Miyako Islands in August 1985
Solid and open circles show wild and sterile flies, respectively. The size of the circles indicates the number of flies caught.

rearing facility constructed in Naha, Okinawa, could produce 30 million flies per week. Thus, the wild male population had to be reduced prior to the release of the sterile males.

Prior to the release of sterile flies, suppressive control was carried out with the male annihilation technique, by distributing a cotton string soaked with cue-lure (a male attractant) and BRP (an insecticide) from a helicopter. The cotton string cut into pieces 5 cm in length, was distributed once a month at a rate of 40 strings per ha. At the final stage of the suppression, the wild male population density decreased to less than 1/20 of that in the same season before the control.

From August 1984, 30 million sterile flies per week were released from a helicopter evenly on Miyako Islands. In the initial 7 months of the release, sterile fly population level was low (Fig. 4), due to seasonal effect and also to the decrease in the flight ability, possibly caused by pupal sifting from pupation bed[16]. The flight ability was improved by carrying out pupal sifting 5–6 days after pupation instead of 3 days. Fig. 2 shows the distribution of the sterile and wild melon flies using monitoring traps baited with toxic cue-lure on Miyako Islands in August 1985. There were high density areas, called "hot spots"[17] in some parts of the Shimoji area which is a vegetable (including hosts of the melon fly)-producing area on the island. As this characteristic was considered to be conducive to the reproduction of the melon fly, we decided to release additional 6 million sterile flies per week into the Shimoji area. Fig. 3 shows the additional release areas on Miyako Islands. The second additional release was carried out in Ueno and a part of the Hirara area where new hot spots were detected. The third additional release involved wider areas to achieve the eradication as quickly as possible.

As a result of these additional releases, the wild fly population decreased and no wild flies had been caught by monitoring traps since February 1987 (Fig. 4). Fig. 5 shows the change in the infestation rate of host fruits on Miyako Islands. Until April 1986, the percentage of the infestation ranged between 0.1 and 10. However, from May 1986, it rapidly decreased and became 0 after November

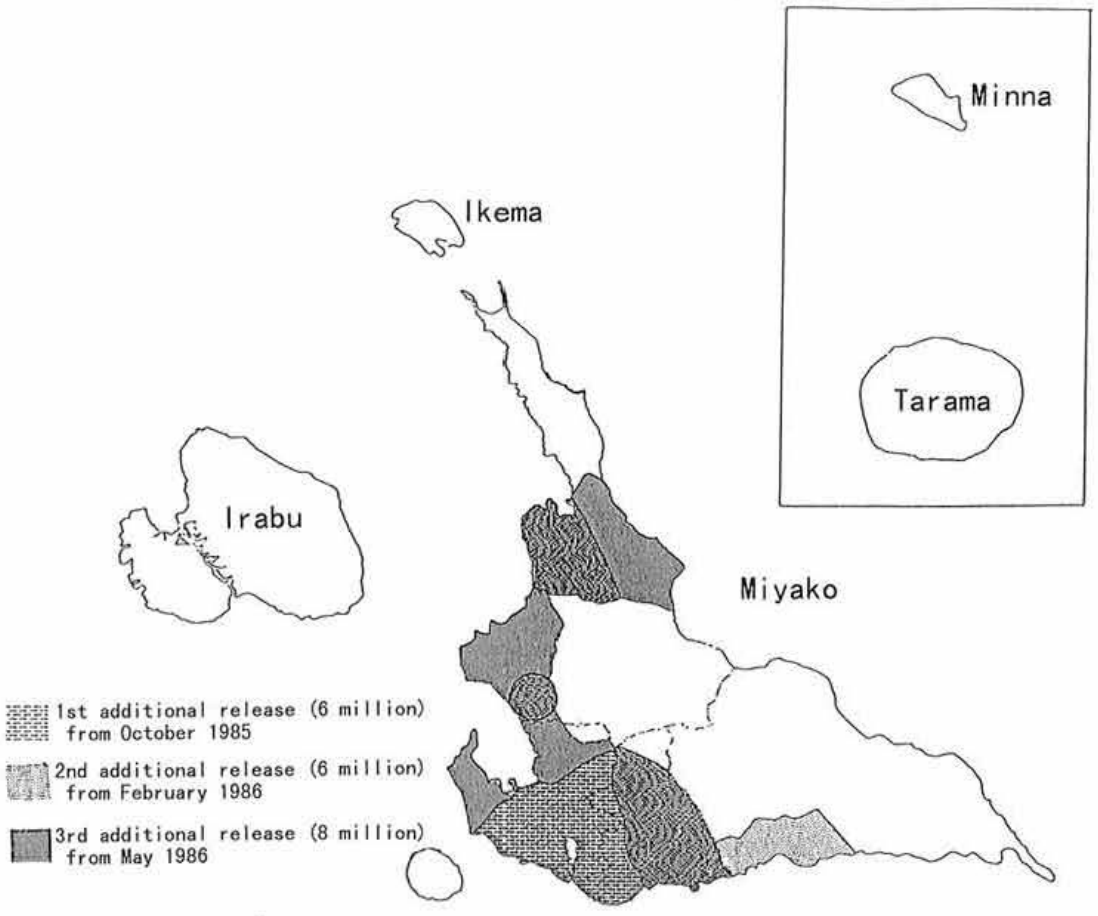

Fig. 3. Additional release areas on Miyako Islands

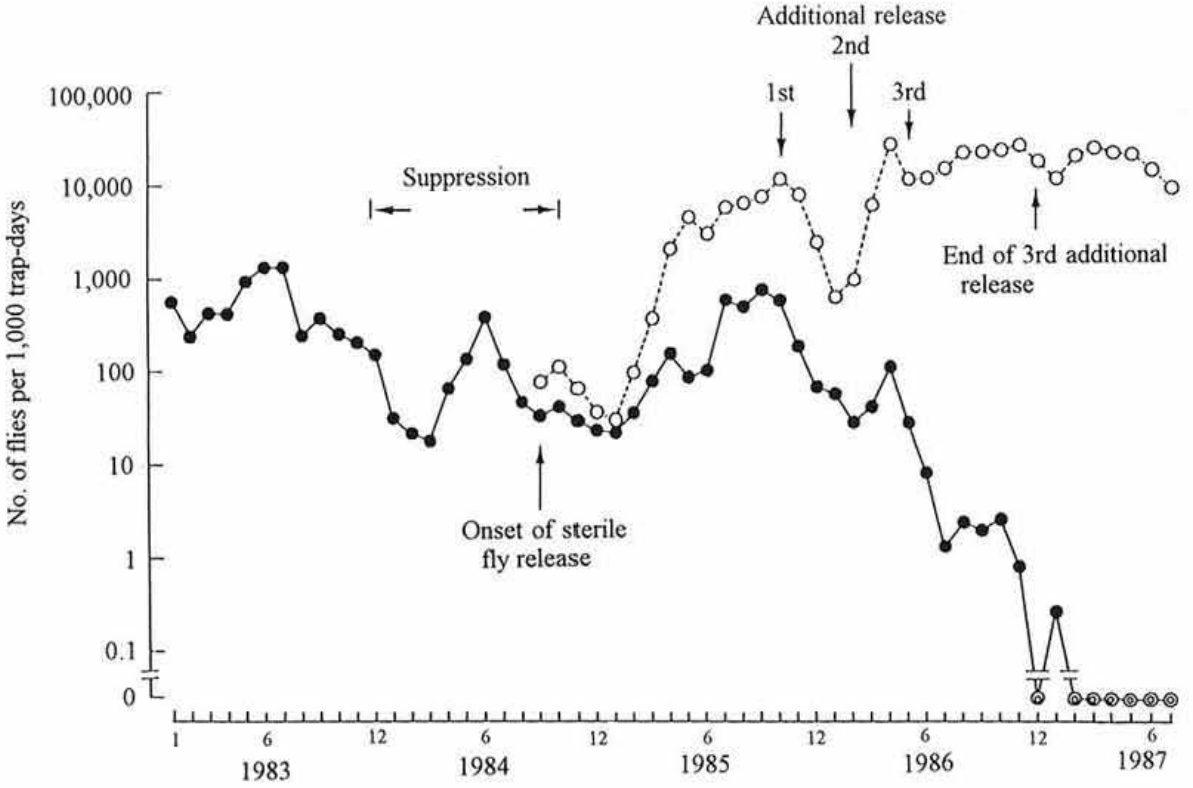

Fig. 4. Monthly changes in relative abundance of sterile and wild melon flies caught by monitoring traps on Miyako Islands
Solid and open circles indicate wild and sterile melon flies, respectively.

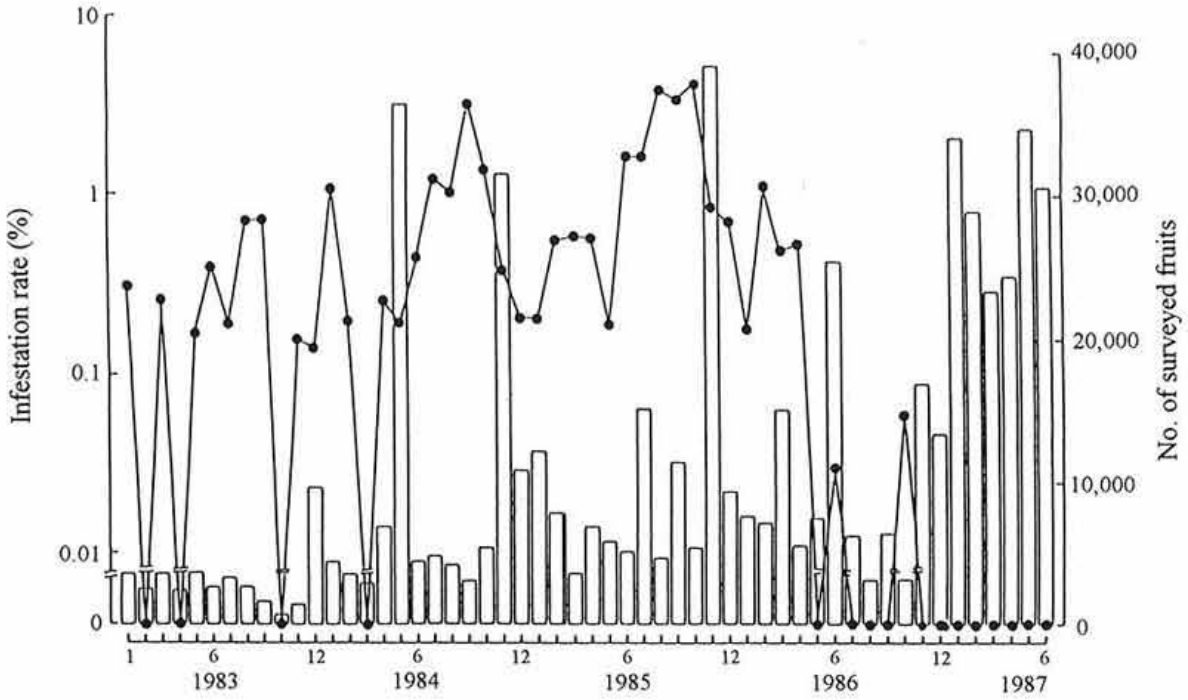

Fig. 5. Infestation rate of the melon fly in host fruits on Miyako Islands
Histogram shows the number of surveyed fruits.

1986. These data suggested that the melon fly eradication on Miyako Islands had been achieved[9].

Okinawa Islands project

The large scale eradication project proceeded to Okinawa Islands (1,379 km^2). The total number of wild flies on Okinawa Islands was estimated to be 110 million flies at the peak season[14] by adjusting the data estimated by Koyama et al.[12]. On the Okinawa Islands, which are the largest island group in the prefecture, an eradication sub-project began in 1986 when the SIT on Miyako Islands was still being implemented and the number of sterile flies produced had not been sufficient. Therefore, the control was initiated in the southern part of the islands and the control area was expanded gradually toward the northern part of the islands.

Prior to the release of sterile flies, suppressive control with the male annihilation technique as described before was carried out in the southern part of the Okinawa Islands, where the population density was highest in the islands. In the final stage of the suppression, the wild male population density in the area decreased to about 1/20 of that in the same season before the control. Then 87 million sterile flies were released weekly from November 1986 in this area. At the same time, suppressive control using the male annihilation technique was started in the northern part of the islands except in the mountainous area where the population density was low[12], and it was continued until the start of SIT. The number of sterile flies released and areas where the release was carried out on Okinawa Islands increased as shown in Fig. 6.

In the initial stage of the SIT, sterile flies were released uniformly all over the control area. After, when our monitoring trap system enabled to detect

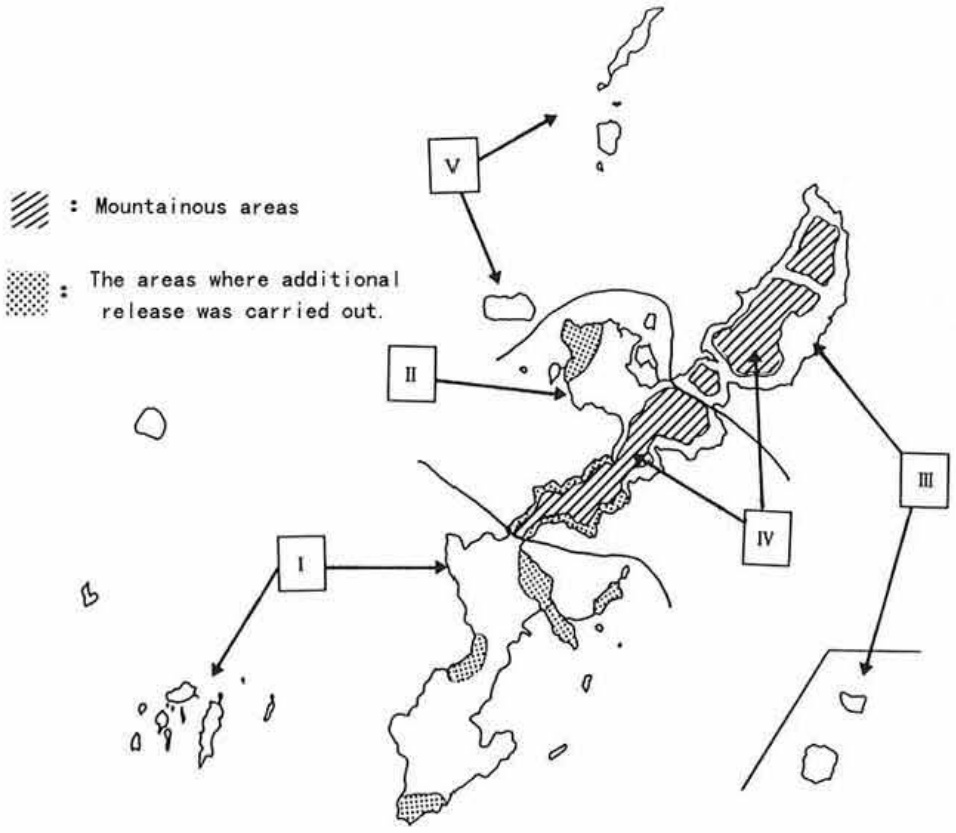

Fig. 6. Progress in release of sterile flies on Okinawa Islands
I: 87 million flies per week were released from November 1986. II: 20 million flies per week were released from March 1987. III: 40 million and 6 million flies per week were released on Okinawa Islands and Daito Islands, respectively, from January 1988. IV: Release area expanded to all the northern part of Okinawa Island from II & III, from April 1988. V: 7 million flies per week were released from July 1988. Shaded areas: The areas where additional release was carried out.

the location of hot spots, we released additional sterile flies around the hot spots. These additional releases were very effective in achieving the eradication of the melon fly quickly. Figs. 7 and 8 show the results of the monitoring traps and host fruit survey on Okinawa Islands, respectively. The survey data showed that no wild flies and no infested fruits were detected since December 1989, in Okinawa Islands. Based on these data, eradication of the melon fly on Okinawa Islands was officially announced in November 1990[10].

Yaeyama Islands project

In Yaeyama Islands (585 km^2), which was the final target area of eradication of the melon fly in the prefecture, the eradication project began in October 1989. After suppressive control using the

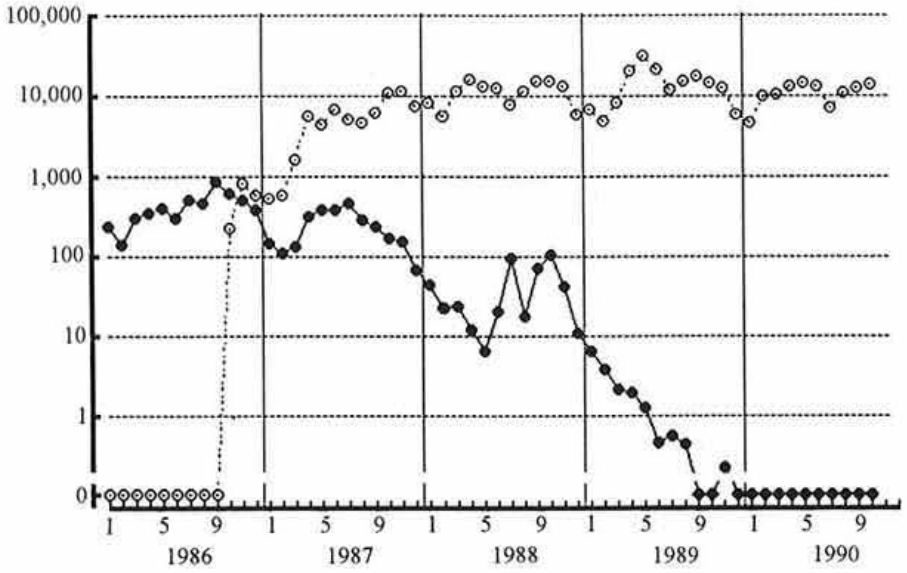

Fig. 7. Monthly change in relative abundance of sterile and wild melon flies caught by monitoring traps on Okinawa Islands
Solid and open circle indicate wild and sterile flies, respectively.

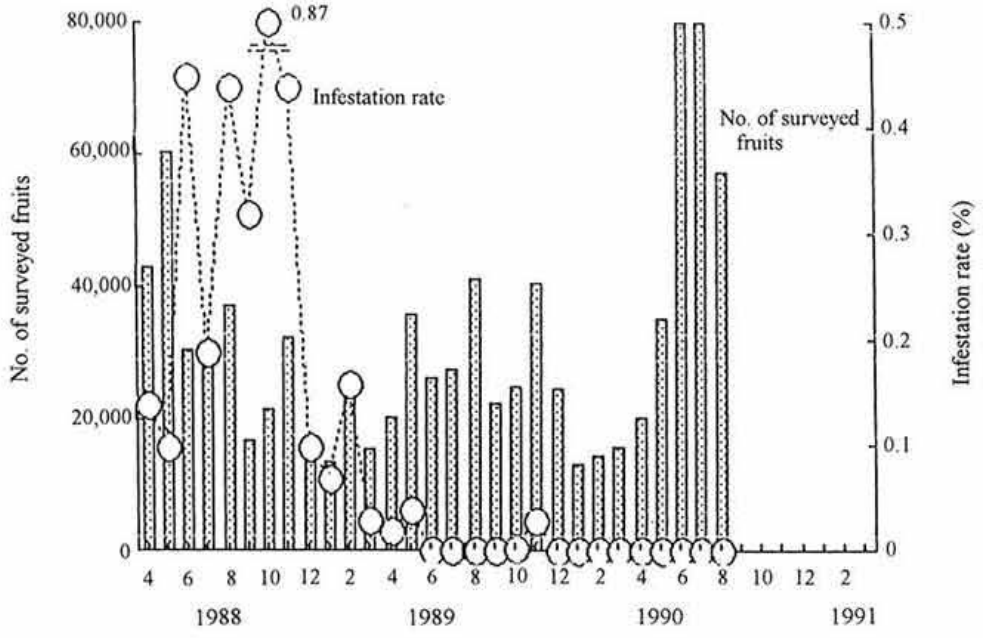

Fig. 8. Infestation rate of the melon fly on host fruits on Okinawa Islands

male annihilation technique for about 3 months, 44 million sterile flies were released weekly on Ishigaki and Taketomi Islands of the Yaeyama group from January 1990. In the other areas of Yaeyama Islands, the suppressive control was initiated in May and 43 million sterile flies were released weekly from November 1990. The data of traps and host fruit survey (Figs. 9 & 10) indicated that no wild flies and no infested fruits had been detected since September and June 1991, respectively. The eradication of the melon fly on Yaeyama Islands was officially announced in 1993[11].

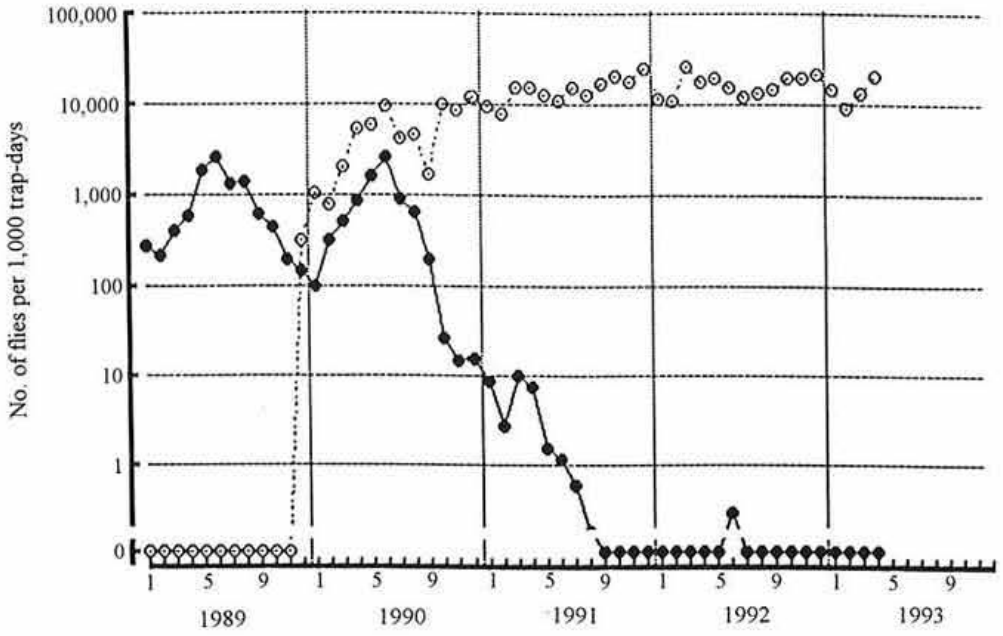

Fig. 9. Monthly change in abundance of sterile and wild melon flies caught by monitoring traps on Yaeyama Islands
Solid and open circles indicate wild and sterile flies, respectively.

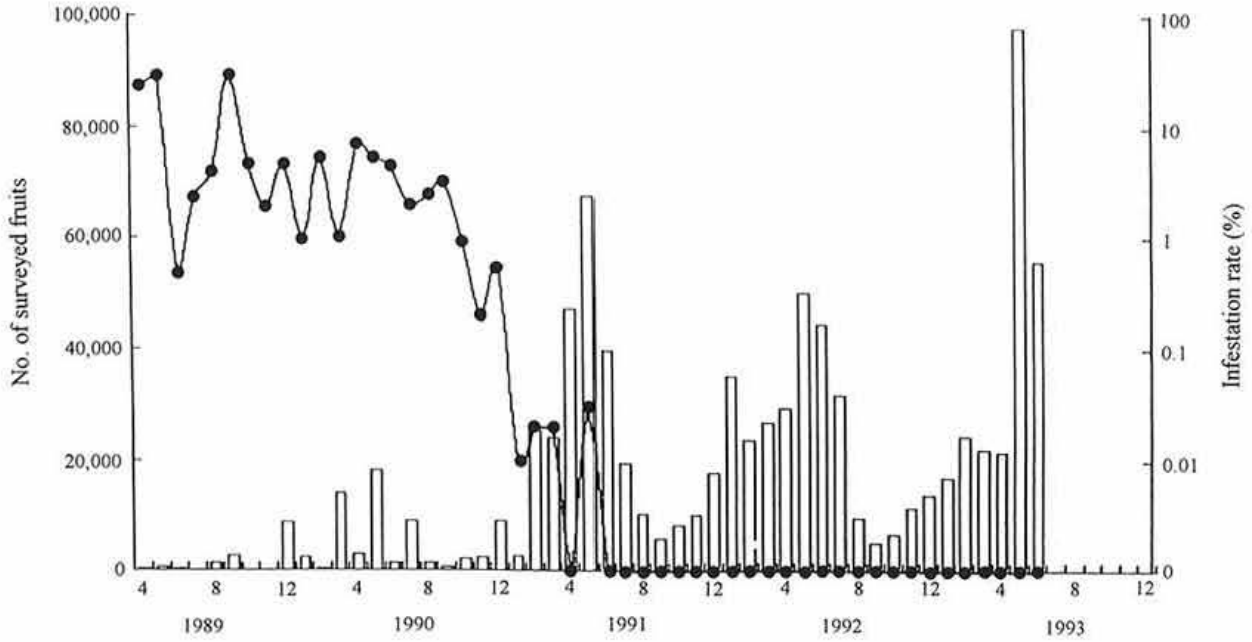

Fig. 10. Infestation rate of the melon fly on host fruits on Yaeyama Islands
Histogram shows the number of surveyed fruits.

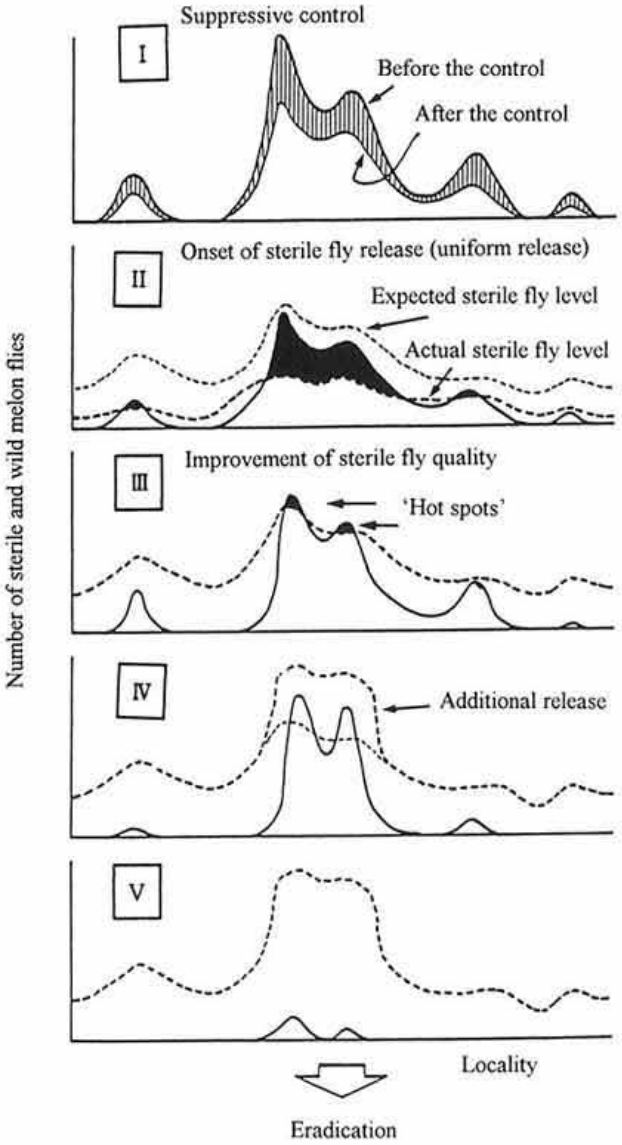

Fig. 11. Schematic representation of the sequence of application of SIT of the melon fly on Miyako Islands

In horizontal axis, 2-dimentional location is expressed as one dimension for convenience. I: Wild male population was reduced initially through the male annihilation technique. II: Sterile flies were released uniformly. However, sterile fly population level was not sufficient because of the low flight ability. High density areas of wild fly in certain parts became conspicuous. III: By qualitative improvement, sterile fly population was increased. However, it was insufficient to suppress the reproductive rate of the wild fly in the hot spots. IV: By additional release, the ratio of sterile to normal (wild) flies in hot spots increased. V: The ratio of sterile to normal (wild) flies increased drastically, and the eradication was achieved.

Conclusion

Fig. 11 shows the sequence of application of SIT on Miyako Islands[8]. In the first stage (I), suppressive control with male annihilation technique was carried out. As cotton strings impregnated with lure-toxicant were distributed evenly, we expected that the local population density would be reduced in a density-independent manner. After the population suppression, in stage II, we started SIT. Sterile flies were released uniformly. To some extent, the released flies moved to areas with a high density of wild flies[12], but the density of the sterile flies was lower than the expected level (broken lines). Then, the density of the sterile flies was insufficient to suppress the reproduction of the wild flies in certain areas. The insufficiency was caused by the low flight ability of the released flies and also by the high density of wild flies in hot spots due to favorable reproductive conditions. In this stage, S/N values of all traps were less than 10 and even less than 1 (minimum). In stage III, the sterile fly population level increased by qualitative improvement, and the S/N values of all the traps ranged between 10 and 100 and even between 1 and 10 (minimum). However, the number was insufficient to suppress the reproductive rate of the wild flies in hot spots. Then, we released additional flies to the hot spots in stage IV, and the S/N values in the hot spots increased. In this stage, the S/N values of all the traps ranged between 100 and 1,000 and even 10 and 100 (minimum). In stage V, when the S/N values increased markedly in all the traps, exceeding 100, the eradication was considered to be successful.

Our experience in the Miyako Islands project indicates that the quality of sterile flies and additional release of these on hot spots are very important for the success of the eradication. At first, when we released sterile flies uniformly, we did not consider that the wild flies were distributed uniformly over the target area. We expected that the distribution of the sterile flies would overlap that of wild flies and help us detect hot spots. We were thus able to perform additional releases to the hot spots. The additional releases based on the S/N values from field trap data appeared to be a good strategy for the success of SIT. This strategy was applied in the Okinawa and Yaeyama Islands project and we obtained successful results also. Detailed field studies on the distribution pattern of the wild flies are essential for the success of SIT.

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