Melon Fly, Bactrocera Cucurbitae (Diptera: Tephritidae), Infestation in Host Fruits in the Southwestern Islands of Japan before the Initiation of Island-wide Population Suppression, as Recorded in Publications of Japanese Public Institutions

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Melon Fly, *Bactrocera cucurbitae* (Diptera: Tephritidae), Infestation in Host Fruits in the Southwestern Islands of Japan Before the Initiation of Island-wide Population Suppression, as Recorded in Publications of Japanese Public Institutions

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ABSTRACT: *Bactrocera cucurbitae* (Coquillett) is a tephritid fruit fly native to the Indo-Malayan region. Its distribution, though, has extended to include Africa, temperate Asia, and a number of Pacific islands. It became established in Japan in 1919 in the Yaeyama Islands and spread north in the Southwestern Islands of Japan. It was subsequently eradicated from these islands by an eradication program that extended from 1972 to 1993. As part of an effort to develop a worldwide database on the status of fruits as hosts of melon fly, the infestation data gathered from host fruits collected in this eradication program, before the initiation of suppression activities, are summarized here. *Bactrocera cucurbitae* infestation was documented in 24 plant taxa of four plant families (Caricaceae, Cucurbitaceae, Moraceae, and Solanaceae), with the following four new hosts identified: *Ficus erecta* Thunb., *F. pumila* L. (Moraceae), *Solanum erianthum* D. Don (Solanaceae), and *Zehneria liukiuensis* Jeffrey ex Walker (Cucurbitaceae).

KEYWORDS: *Bactrocera cucurbitae*, melon fly, host plant, infestation, eradication, fruit fly

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Introduction

Bactrocera cucurbitae (Coquillett) is a tephritid fruit fly native to the Indo-Malayan region.[1] Its distribution has extended to include Africa, temperate Asia, and a number of Pacific Islands.[2] It became established in Japan in 1919, where it was first detected in the Yaeyama Islands, the most southern islands. Melon fly subsequently spread north in the Southwestern Islands of Japan to the Miyako Islands (1929), Kume Island (1970), the Okinawa Islands (1972), Yoron and Okierabu Islands (1973), Tokunoshima Island, the Amami-Oshima Islands, and Kikai Island (1974). The melon fly also subsequently spread to the Daitoh Islands (1977) (Fig. 1).[3] Melon fly is a very serious pest of cucurbit crops, but also attacks fruits in a number of other plant families.[2] Adult female melon flies lay eggs in these fruits, potentially even before the flower opens. Subsequent larval feeding can cause considerable fruit damage that ruins the crop for local consumption and necessitates the development of quarantine protocols to prevent the introduction of this pest to other areas where this pest is not established.[1]

In 1972, the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan and the Okinawa Prefectural Government (OPG) initiated an experimental melon fly eradication program based on the use of sterile insect technique (SIT) in one of these islands (Kume Island). Following successful eradication there in 1978, eradication efforts were extended to the Miyako, Okinawa, and Yaeyama groups of Islands, in 1984, 1986, and 1989, respectively, with eradication achieved in 1987, 1990 and 1993, respectively.[4] Overall, this eradication program is one of the highlights in the history of melon fly control. Over the course of this successful program, many fruits were collected and held for the assessment of infestation by melon fly. The infestation data were published in a number of in-country reports, all written in Japanese, which have not been readily accessible by people outside of Japan. As part of an effort to develop a worldwide database on the status of fruits as hosts of melon fly, we reviewed and summarized the fruit infestation data gathered from host fruits collected before the initiation of suppression activities (bait sprays, male annihilation, and sterile fly releases). This summarization is of particular value because of the quantity of data collected and the fact that there is no longer any infestation of these fruits in Japan; so this paper provides historical documentation of melon fly hosts in Japan.

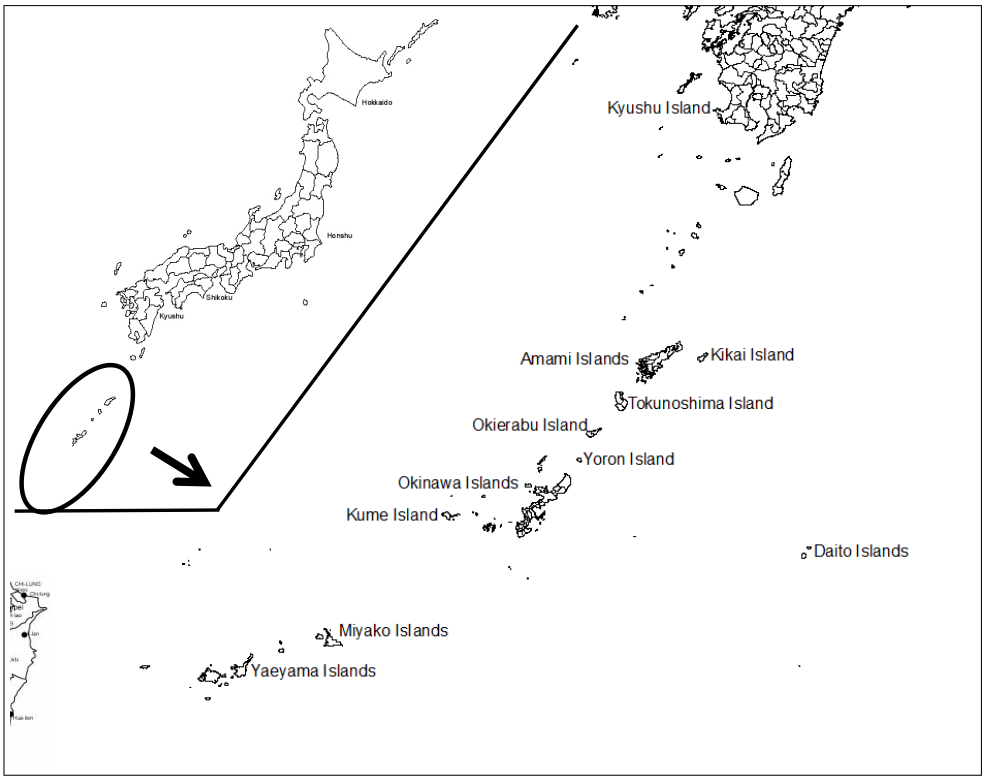

Figure 1. Japan, with enlargement of the Southwestern Islands of Japan, where the successful melon fly eradication campaign was conducted. Outline maps of Japan and Taiwan modified from world map clipart source,[48] with enlarged Southwestern Islands of Japan obtained from GADM[49] and incorporated into the final figure using ArcGIS.[50]

This summarization will also be of value should melon fly ever become re-established on any of the Southwestern Islands of Japan, for use in pest risk assessments and in contributing to our overall understanding of the host range of the melon fly.

Materials and Methods

Data collection. Throughout the course of the eradication program, results of efforts on the different islands were summarized in government documents published on an annual basis. Agencies responsible for these publications included the South Plant Protection Office, The Miyako Plant Protection Office, the Department of Agriculture, Forestry and Fishery of Okinawa and Kagoshima Prefectures. These publications included data tables that summarized what cultivated and wild species of fruits were collected, the numbers of fruits collected and assessed for infestation by melon fly, and the numbers of fruits found to be infested. These summaries included fruit collections made before the start of suppression efforts, and continued until eradication was declared. Here, we used data only from the fruit collections made before the start of any island-wide melon fly suppression efforts (though individual farmers were utilizing some conventional controls on their farms) in order to present natural infestation rates. The dates of pre-suppression fruit sampling, suppression by bait sprays and male annihilation, and suppression by SIT are given in Table 1 for the islands involved in the eradication program.

Methods description of fruit collections made in the course of the eradication program indicates that collected fruits were examined and those that were found to be rotten (which could be a result of tephritid fruit fly infestation) were dissected within 3 days after they were collected. If larvae were detected, they were allowed to continue to develop inside the fruits, with the fruits placed on sawdust or sand in small plastic cups. After 2 weeks, the sawdust or sand was sieved to collect the pupae. Pupae were placed in a Petri dish inside cages until adult emergence.[5] Fruits that were not found to be rotten were similarly held on sand in plastic containers for 2–3 weeks at ambient temperature, after which time containers were checked for pupae and/or adult insects, with pupae held as described above until adult emergence.[6] Species identification of emerged adults was based on reference to Drew (1989).[7]

Data presentation. Plant species from which fruits were collected are presented in alphabetical order by genus, within an alphabetical listing of plant families. For each plant species listed, common names in both English and Japanese are given, where possible (Table 2). Japanese common names used were based on the *Flora of the Ryukyus, South of Amami Island*,[8] with minor exceptions. Scientific names used are, where possible, based on GRIN (Germplasm Resources Information Network) taxonomy for plants.[9] For species not included in the GRIN database, names used were based on the *Flora of the Ryukyus, South of Amami Island*.[8] In cases where current scientific names

Table 1. Dates of fruit collections, by Island or Island group, taken before the start of melon fly population suppression, as well as dates of bait spray and male annihilation (MA), dates of sterile insect technique (SIT), and dates of declaration of melon fly eradication.

ISLAND	FRUIT COLLECTIONS BEFORE INITIATION OF SUPPRESSION	BAIT SPRAY APPLICATION AND MALE ANNIHILATION	STERILE INSECT TECHNIQUE	DATE OF ERADICATION ACHIEVEMENT
Kume Island	Aug.–Nov. 1972	Dec. 1972–Dec. 1974	Feb. 1975–Aug. 1976	Sept. 1978
Miyako Islands	Feb. 1975–Nov. 1983	Dec. 1983–Oct. 1984	Aug. 1984–Dec. 1986	Nov. 1987
[1]Amami Islands	Apr. 1976–Dec. 1984	Feb. 1985–May 1987	Sept. 1985–Nov. 1989	Nov. 1987
Okinawa Islands	May 1975–Oct. 1985	Nov. 1985–Nov. 1986	Nov. 1986–Oct. 1990	Nov. 1990
Yaeyama Islands	July 1981–Sept. 1989	Oct. 1989–Jan. 1990	Jan. 1990–Apr. 1993	Oct. 1993

Notes: [1]Amami Islands—dates varied among Islands; bait sprays were started earlier than indicated here on Kikai Island (Jan.–July, 1981); timing of starting SIT also varied among Islands.

Table 2. Scientific and common names of fruits collected in the Southwestern Islands of Japan for assessment of infestation by melon fly. Those fruits from which melon fly was recovered are listed first followed by fruits collected from which no melon fly was recovered.

PLANT FAMILY	PLANT SPECIES SCIENTIFIC NAME	INFESTATION FOUND?	PLANT SPECIES COMMON NAMES	
			JAPANESE	ENGLISH
Caricaceae (パパイア科)	*Carica papaya* L.	Yes	パパイヤ[1]	Papaya
Cucurbitaceae (ウリ科)	*Benincasa hispida* (Thunb.) Cogn.	Yes	トウガ	Wax gourd, white-pumpkin
			トウガン[2]	
	Citrullus lanatus (Thunb.) Matsum. and Nakai	Yes	スイカ	Watermelon
	Cucumis melo L.	Yes	メロン	Cantaloupe
	Cucumis melo L. cv. Albus	Yes	シロウリ	
	Cucumis sativus L. var. sativus[3]	Yes	キュウリ	Cucumber
	Cucurbita maxima Duchesne & *C. moschata* Duchesne	Yes	カボチャ[4]	Pumpkin
	Cucurbita pepo L.	Yes	ズッキーニ	Zucchini
			ツルナシカボチャ	
			セイヨウカボチャ*	
	Diplocyclos palmatus (L.) C. Jeffrey	Yes	オキナワスズメウリ	Lollipop climber
	Lagenaria siceraria (Molina) Standl. cv. *Gourda*	Yes	ヒョウタン*	
			ヒョータン**	
	Lagenaria siceraria (Molina) Standl. cv. *Hispida*[5]	Yes	ユウガオ*	Bottle gourd
			ユーガオ**	(Kagoshima spelling)
	Luffa aegyptiaca Mill.[6]	Yes	ヘチマ	Smooth luffa, sponge gourd
	Momordica charantia var. *pavel* Crantz[5]	Yes	ニガウリ*	Bitter melon
			ツルレイシ	(Kagoshima spelling)
	Sechium edule (Jacq.) Sw.	Yes	ハヤトウリ	Chayote
	Trichosanthes ovigera Bl.[5]	Yes	ケカラスウリ*	Snake gourd
			カラスウリ	
	Trichosanthes tricuspidata Lour.[7]	Yes	オオカラスウリ	
	Zehneria liukiuensis (Nakai) Jeffrey ex Walker[5]	Yes	クロミノオキナワスズメウリ*	
			クロミノスズメウリ**	
Moraceae (クワ科)	*Ficus erecta* Thunb.	Yes	イヌビワ	
	Ficus pumila L.	Yes	オオイタビ	Climbing fig

(*continued*)

Table 2. (*Continued*)

PLANT FAMILY	PLANT SPECIES SCIENTIFIC NAME	INFESTATION FOUND?	PLANT SPECIES COMMON NAMES	
			JAPANESE	ENGLISH
Solanaceae (ナス科)	*Capsicum annuum* L. cv. *Acuminatum*[8]	Yes	トウガラシ	
	Capsicum annuum L. cv. *Glossum*-1[9]	Yes	ピーマン	
	Solanum erianthum D.Don	Yes	ヤンバルナスビ	Potato-tree, big eggplant
	Solanum lycopersicum L. var. *lycopersicum*-1[10]	Yes	トマト*	Tomato
	Solanum lycopersicum L. var. *lycopersicum*-2[10]	Yes	プチトマト	Tomato
	Solanum melongena L.[5]	Yes	ナス*	Eggplant
			ナスビ**	
Anacardiaceae (ウルシ科)	*Mangifera indica* L.[5]	No	マンゴウ*	Mango
			マンゴー**	
Cucurbitaceae (ウリ科)	*Cucumis maderaspatana* L.[11]	No	サンゴジュスズメウリ	
Fabaceae (マメ科)	*Phaseolus vulgaris* L.[5]	No	インゲンマメ*	Green bean
			インゲン	
Malvaceae (アオイ科)	*Abelmoschus esculentus* (L.) Moench	No	オクラ	Okra
Moraceae (クワ科)	*Ficus thonningii* Blume[12]	No	ガジュマル	
Passifloraceae (トケイソウ科)	*Passiflora edulis* Sims	No	クダモノトケイソウ	Passion fruit
Solanaceae (ナス科)	*Capsicum annuum* L. cv. *Conoides*[8]	No	ナナイロトウガラシ	
			ゴシキトウガラシ*	
	Capsicum annuum cv. *Glossum*-2[9]	No	シシトウガラシ	
	Capsicum annuum L. cv. *Parvo-acuminatum*	No	タカノツメ	
	Capsicum frutescens L.	No	シマトウガラシ	Tabasco pepper
			キダチトウガラシ*	
	Solanum capsicoides All.[13]	No	キンギンナスビ	
	Solanum mammosum L.	No	ツノナス	Fox face
	Solanum seaworthianum Andrews	No	フサナリツルナスビ	

Notes: [1]Japanese names presented are as used in the government publications. These are standard Japanese common names as presented in the *Flora of the Ryukyus, South of Amami Island*,[8] unless noted otherwise. In cases where the Japanese common name differed from that presented in the *Flora of the Ryukyus, South of Amami Island,* the name used in the *Flora of the Ryukyus, South of Amami Island*[8] is also presented, followed by an asterisk. Common names followed by two asterisks are thought to be atypical spellings of the common name, cases where the sound of the word is similar to the standard common name, but the spelling is improper. [2]This second common name used is not listed as a common name in the *Flora of the Ryukyus, South of Amami Island.*[8] [3]Synonym of *Cucumis sativus* var. *tuberculatus* Gabajev, which was the scientific name used in the *Flora of the Ryukyus, South of Amami Island.*[8] [4]*Cucurbita maxima* and *C. moschata* were not differentiated in fruit collections. Both were listed under the common name "カボチャ." The *Flora of the Ryukyus, South of Amami Island*[8] lists the common names for these two species as クリカボチャ and ニホカボチャ, respectively. [5]Two different common names were used, one of which is the name used in the *Flora of the Ryukyus, South of Amami Island*[8] (as indicated by the asterisk). Data from the two common names were combined. [6]Synonym of *Luffa cylindrica* (L.) M. Roem., which was the scientific name used in the *Flora of the Ryukyus, South of Amami Island.*[8] [7]Synonym of *Trichosanthes bracteata* Lour., which was the scientific name used in the *Flora of the Ryukyus, South of Amami Island.*[8] [8]cv. *Acuminatum* and cv. *Conoides* are both considered to be synonyms of *C. annuum* L. var. annuum, but were summarized separately here because of the differential use of the common name. [9]Synonym of *Capsicum annuum* L. var. *annuum*; but the name used in the in-country publications (*Capsicum annuum* L. cv. *Glossum-1*) is used because of the diversity of taxa now considered to be included in *Capsicum annuum* L. var. *annuum*; the Japanese common names for cv. *Glossum-1* and cv. *Glossum-2* are presented as being synonymous in the *Flora of the Ryukyus, South of Amami Island.*[8] However, because they are treated as different commodities in the Japanese market, the data from the two common names were summarized separately. [10]Synonym of *Lycopersicon esculentum*, which was the scientific name used in the *Flora of the Ryukyus, South of Amami Island*[8]; data for the two common names were summarized separately. [11]Synonym of *Mukia maderaspatana* (L.) M. Roem., which was the scientific name used in the *Flora of the Ryukyus, South of Amami Island.*[8] [12]Synonym of *Ficus microcarpa* L. f., which was the scientific name used in the *Flora of the Ryukyus, South of Amami Island.*[8] [13]Synonym of *Solanum ciliatum* Lam., which was the scientific name used in the *Flora of the Ryukyus, South of Amami Island.*[8]

differ from older names used in publications, the host data are presented under the currently accepted scientific name, with footnotes indicating the scientific name used in the original publications. There were several cases where more than one common name was used for a plant species (see Table 2). In some cases (eg, common names used for *Momordica charantia* var. *pavel* Crantz), this just represented different common names used on different Islands, so data from the two names were combined. However, in another case (ie, *Capsicum annuum* cv. Glossum), although the two common names are considered

in the *Flora of the Ryukyus, South of Amami Island*[8] to refer to the same species, they are treated in the Japanese market as different commodities, so the data were kept separate. The approach taken (ie, combining data or keeping data separate) for each species for which two common names were used is indicated in Table 2. Data are summarized by five island groups: Amami Islands, Kume Island, Miyako Islands, Okinawa Islands, and Yaeyama islands. Data sources, by Island, are as follows: Amami Islands:[10–18].Kume Island:[19]. Miyako Islands:[20–29]. Okinawa Islands:[26,27,29–38]. Yaeyama Islands:[26,27,29,37–42]. The total number of fruit collections made, total numbers of collections made where infestation was detected, total numbers of fruits collected, total numbers of infested fruits, and average percentage *B. cucurbitae* infestation are presented by Island groups for each plant species. The overall average percentage infestation across all island groups was calculated for each collected plant species as an average weighted by the number of fruit collections made in each island group (ie, averages from Islands where more collections were made had greater weight in the overall weighted average; Footnote 2 in Table 3 provides a sample of the weighted average calculation). A collection is defined here as an entry into a summary table. These entries may represent the sum of collections made at a number of different sites, but are typically collections made over the course of 1 month. Although the summary publications sometimes indicate the number of sites from which fruits were collected, this was not always the case, which is why the line/month total was used as an indication of a collection. One deviation from this were the 1979 data for Okinawa, where the published monthly data only included monthly collections where infestation was recovered. A summary table, however, indicated the total number of infested fruits and total number of fruits collected over the course of 1979.[33] The latter data were used for our summarization, because it more accurately represented the infestation rate.

Results

Over 1.1 million fruits were collected before the start of population suppression efforts over the course of the *B. cucurbitae* eradication program (the sum of fruit numbers listed in Tables 3 and 4). These fruits encompassed 39 different plant taxa, of eight plant families, of which infestation was found in 24 taxa (spread across four plant families) (see Tables 3 and 4). Data on collections of taxa from which melon fly was recovered are summarized in Table 3, with references used for each island or island group noted in a footnote to the table. Included there are the total number of collections made for each plant species, the number of collections where melon fly infestation was found, the total number of fruits collected, the total number of infested fruits recovered, and the overall infestation rate. Data on collections of taxa from which melon fly was not recovered are summarized in Table 4. Infestation was found in four plant families: Caricaceae, Cucurbitaceae, Moraceae and Solanaceae. Most of the host fruit species were in the family Cucurbitaceae (15 species). Solanaceae was the plant family with the second most number of host species (6 species). In addition to fewer recorded solanaceous host species than cucurbitaceous host species, infestation rates were considerably lower in solanaceous hosts than in cucurbitaceous hosts. The identified hosts in the plant family, Moraceae, were both very poor hosts, with infested fruits found in only one fruit collection for each species, despite collection numbers exceeding 12,000 (*Ficus pumila*) and 34,000 (*F. erecta*). The highest overall infestation rates came from *Cucurbita pepo* (33.3%; zucchini squash), but this was based on a rather small sample size (13 fruits). The next highest infestation rate was found in *Momordica charantia* (21.6%; bittermelon) followed by *Trichosanthes ovigera* (17.7%; snake gourd), *Cucumis melo* (17.2%; cantaloupe), *Lagenaria siceraria* cv. *gourda* (16.7%; bottle gourd), and *Luffa aegyptiaca* (15.3%; smooth luffa), all cucurbitaceous crops.

Discussion

Comparing the results presented here with *B. cucurbitae* host listings reported by other authors,[43–47] there are four new *B. cucurbitae* host species reported in the data reported herein, which had not previously been reported, as well as several new varieties of host species that had previously not been listed by other authors. The four new host species are *Ficus erecta*, *F. pumila*, both in the plant family Moraceae, *Solanum erianthum* (Solanaceae), and *Zehneria liukiuensis* (Cucurbitaceae). Earlier host listings for *B. cucurbitae* had included other Moraceae species, such as *Ficus carica* L.[45,46] and *F. chartacea*,[43,44] but we are unaware that the two *Ficus* species reported here as melon fly hosts have previously been listed as *B. cucurbitae* hosts outside of the Okinawa publications related to the melon fly eradication program. Infestation rates for these two *Ficus* species were not high. For *F. erecta*, only three fruits were found to be infested out of 34,749 collected fruits, and the average percentage infestation rate was only 0.0025%. For *F. pumila,* only seven fruits were found to be infested out of 12,101 collected fruits, and the average percentage infestation rate was only 0.015%. The overall average infestation rate of *S. erianthum* was higher than for the *Ficus* spp. (3.3%), but varied from 0.0% to 8.0% among island groups. The last of the four new host species identified here for melon fly, *Zehneria liukiuensis*, supported infestation by melon fly in 30.0 to 50.0% of collections, but the average percentage infestation rate was low, only averaging 1.4%. In the 1983 publication reporting on the infestation rate of host fruits of melon fly in the Yaeyama Islands in 1982,[27] it was reported that ten *Trichosanthes kirilowii* Maxim.(Cucurbitaceae) fruits were collected of which one (10%) was found to be infested by *B. cucurbitae*. This would be an additional new *B. cucurbitae* host. However, we think that these fruits were incorrectly designated as *T. kirilowii* fruits because *T. kirilowii* is listed by the *Flora of the Ryukyus* to only occur in the Amami Islands and not in the Yaeyama Island group. Additionally, such an error could stem from the close similarity of spelling and sound of the representative common names in Japan: キカラスウリ

Table 3. Hosts of the melon fly in the Southwestern Islands of Japan before initiation of suppression activities leading to melon fly eradication. Data taken from publications of Japanese public institutions, in which collection data are presented by Island by date.[1]

FAMILY	SCIENTIFIC NAME	ISLAND	TOTAL NUMBER OF			COLLECTIONS WITH *B. cucurbitae* INFESTATION		AVERAGE *B. cucurbitae* % INFESTATION	
			COLLECTIONS	FRUITS	INFESTED FRUITS	NO.	%	ISLAND	OVERALL[2]
Caricaceae	*Carica papaya* L.	Amami	16	468	0	0	0.0	0.0	0.31
Caricaceae	*Carica papaya* L.	Miyako	23	1,585	0	0	0.0	0.0	
Caricaceae	*Carica papaya* L.	Okinawa	14	319	0	0	0.0	0.0	
Caricaceae	*Carica papaya* L.	Yaeyama	42	534	9	3	7.1	0.71	
Cucurbitaceae	*Benincasa hispida* (Thunb.) Cogn.	Amami	13	1,020	2	1	7.7	0.034	10.6
Cucurbitaceae	*Benincasa hispida* (Thunb.) Cogn.	Kume	3	63	24	3	100.0	38.1	
Cucurbitaceae	*Benincasa hispida* (Thunb.) Cogn.	Miyako	2	100	0	0	0.0	0.0	
Cucurbitaceae	*Benincasa hispida* (Thunb.) Cogn.	Okinawa	21	923	142	13	61.9	12.2	
Cucurbitaceae	*Benincasa hispida* (Thunb.) Cogn.	Yaeyama	6	34	6	3	50.0	17.8	
Cucurbitaceae	*Citrullus lanatus* (Thunb.) Matsum. & Nakai	Amami	15	2,617	59	6	40.0	4.8	10.3
Cucurbitaceae	*Citrullus lanatus* (Thunb.) Matsum. & Nakai	Miyako	5	309	9	2	40.0	3.6	
Cucurbitaceae	*Citrullus lanatus* (Thunb.) Matsum. & Nakai	Okinawa	13	1,206	75	7	53.8	8.4	
Cucurbitaceae	*Citrullus lanatus* (Thunb.) Matsum. & Nakai	Yaeyama	2	214	1	1	50.0	50.0	
Cucurbitaceae	*Cucumis melo* L.	Okinawa	2	63	2	2	100.0	25.8	17.2
Cucurbitaceae	*Cucumis melo* L.	Yaeyama	1	5	0	0	0.0	0.0	
Cucurbitaceae	*Cucumis melo* L. cv. Albus	Amami	8	235	42	3	37.5	8.1	8.1
Cucurbitaceae	*Cucumis sativus* L. var. *sativus*	Amami	114	38,819	770	46	40.4	5.3	8.4
Cucurbitaceae	*Cucumis sativus* L. var. *sativus*	Miyako	11	773	50	8	72.7	7.0	
Cucurbitaceae	*Cucumis sativus* L. var. *sativus*	Okinawa	54	7,476	632	37	68.5	11.3	
Cucurbitaceae	*Cucumis sativus* L. var. *sativus*	Yaeyama	8	140	18	6	75.0	35.9	
Cucurbitaceae	*Cucurbita maxima* Duchesne & *C. moschata* Duchesne	Amami	122	54,633	2,070	46	37.7	4.4	8.0
Cucurbitaceae	*Cucurbita maxima* Duchesne & *C. moschata* Duchesne	Kume	4	77	28	3	75.0	32.1	
Cucurbitaceae	*Cucurbita maxima* Duchesne & *C. moschata* Duchesne	Miyako	1	20	0	0	0.0	0.0	
Cucurbitaceae	*Cucurbita maxima* Duchesne & *C. moschata* Duchesne	Okinawa	39	4,323	340	27	69.2	14.4	
Cucurbitaceae	*Cucurbita maxima* Duchesne & *C. moschata* Duchesne	Yaeyama	16	1,099	56	9	56.2	14.4	
Cucurbitaceae	*Cucurbita pepo* L.	Amami	3	13	5	1	33.3	33.3	33.3
Cucurbitaceae	*Diplocyclos palmatus* (L.) C. Jeffrey	Amami	223	278,300	16,067	148	66.4	4.7	4.1
Cucurbitaceae	*Diplocyclos palmatus* (L.) C. Jeffrey	Kume	4	536	22	2	50.0	5.5	
Cucurbitaceae	*Diplocyclos palmatus* (L.) C. Jeffrey	Miyako	26	14,323	372	18	69.2	4.2	

Cucurbitaceae	*Diplocyclos palmatus* (L.) C. Jeffrey	Okinawa	84	31,464	872	69	82.1	4.0	
Cucurbitaceae	*Diplocyclos palmatus* (L.) C. Jeffrey	Yaeyama	112	67,690	1,572	67	59.8	3.1	
Cucurbitaceae	*Lagenaria siceraria* (Molina) Standl. cv. *Gourda*	Yaeyama	1	6	1	1	100.0	16.7	16.7
Cucurbitaceae	*Lagenaria siceraria* (Molina) Standl. cv. *Hispida*	Amami	1	12	0	0	0.0	0.0	3.7
Cucurbitaceae	*Lagenaria siceraria* (Molina) Standl. cv. *Hispida*	Okinawa	3	15	0	0	0.0	0.0	
Cucurbitaceae	*Lagenaria siceraria* (Molina) Standl. cv. *Hispida*	Yaeyama	2	12	2	1	50.0	11.1	
Cucurbitaceae	*Luffa aegyptiaca* Mill.	Amami	35	1,931	196	18	51.4	7.6	15.3
Cucurbitaceae	*Luffa aegyptiaca* Mill.	Kume	4	121	20	3	75.0	20.6	
Cucurbitaceae	*Luffa aegyptiaca* Mill.	Miyako	3	100	15	2	66.7	15.3	
Cucurbitaceae	*Luffa aegyptiaca* Mill.	Okinawa	30	1,904	259	20	66.7	14.9	
Cucurbitaceae	*Luffa aegyptiaca* Mill.	Yaeyama	25	788	217	17	68.0	25.7	
Cucurbitaceae	*Momordica charantia* var. *pavel* Crantz	Amami	126	33,421	3,181	89	70.6	13.7	21.6
Cucurbitaceae	*Momordica charantia* var. *pavel* Crantz	Kume	4	574	141	4	100.0	38.0	
Cucurbitaceae	*Momordica charantia* var. *pavel* Crantz	Miyako	35	2,845	994	31	88.6	36.6	
Cucurbitaceae	*Momordica charantia* var. *pavel* Crantz	Okinawa	93	20,526	3,381	90	96.8	25.6	
Cucurbitaceae	*Momordica charantia* var. *pavel* Crantz	Yaeyama	27	2,606	1,116	21	77.8	22.4	
Cucurbitaceae	*Sechium edule* (Jacq.) Sw.	Amami	3	213	0	0	0.0	0.0	0.65
Cucurbitaceae	*Sechium edule* (Jacq.) Sw.	Okinawa	3	107	4	1	33.3	1.3	
Cucurbitaceae	*Trichosanthes ovigera* Bl.	Amami	88	9,514	1,266	66	75.0	14.6	17.7
Cucurbitaceae	*Trichosanthes ovigera* Bl.	Kume	1	24	17	1	100.0	70.0	
Cucurbitaceae	*Trichosanthes ovigera* Bl.	Miyako	38	8,511	1,359	36	94.7	17.6	
Cucurbitaceae	*Trichosanthes ovigera* Bl.	Okinawa	9	205	42	7	77.8	22.0	
Cucurbitaceae	*Trichosanthes ovigera* Bl.	Yaeyama	18	372	55	10	55.6	27.7	
Cucurbitaceae	*Trichosanthes tricuspidata* Lour.	Amami	10	232	2	1	10.0	1.1	1.9
Cucurbitaceae	*Trichosanthes tricuspidata* Lour.	Kume	3	38	0	0	0.0	0.0	
Cucurbitaceae	*Trichosanthes tricuspidata* Lour.	Yaeyama	13	199	11	2	15.4	2.9	
Cucurbitaceae	*Zehneria liukiuensis* (Nakai) Jeffrey ex Walker	Amami	94	62,563	630	35	37.2	1.4	1.4
Cucurbitaceae	*Zehneria liukiuensis* (Nakai) Jeffrey ex Walker	Okinawa	11	3,633	12	5	45.4	0.56	
Cucurbitaceae	*Zehneria liukiuensis* (Nakai) Jeffrey ex Walker	Yaeyama	10	784	9	3	30.0	2.2	

(*continued*)

Table 3. (*Continued*)

FAMILY	SCIENTIFIC NAME	ISLAND	TOTAL NUMBER OF			COLLECTIONS WITH *B. cucurbitae* INFESTATION		AVERAGE *B. cucurbitae* % INFESTATION	
			COLLECTIONS	FRUITS	INFESTED FRUITS	NO.	%	ISLAND	OVERALL[2]
Moraceae	*Ficus erecta* Thunb.	Okinawa	19	34,749	3	1	5.3	0.0025	0.0025
Moraceae	*Ficus pumila* L.	Okinawa	19	12,101	7	1	5.3	0.015	0.015
Solanaceae	*Capsicum annuum* L. cv. *Acuminatum*	Amami	1	108	0	0	0.0	0.0	0.0099
Solanaceae	*Capsicum annuum* L. cv. *Acuminatum*	Okinawa	3	485	0	0	0.0	0.0	
Solanaceae	*Capsicum annuum* L. cv. *Acuminatum*	Yaeyama	19	3,766	1	1	5.3	0.012	
Solanaceae	*Capsicum annuum* cv. *Glossum*-2	Amami	73	276,466	6	2	2.7	0.22	0.43
Solanaceae	*Capsicum annuum* cv. *Glossum*-2	Miyako	19	5,884	78	4	22.1	2.0	
Solanaceae	*Capsicum annuum* cv. *Glossum*-2	Okinawa	32	11,489	18	4	12.5	0.50	
Solanaceae	*Capsicum annuum* cv. *Glossum*-2	Yaeyama	42	4,068	4	1	2.4	0.025	
Solanaceae	*Solanum erianthum* D. Don	Miyako	2	130	8	1	50.0	8.0	3.2
Solanaceae	*Solanum erianthum* D. Don	Yaeyama	3	659	0	0	0.0	0.0	
Solanaceae	*Solanum lycopersicum* L. var. *lycopersicum*-1	Amami	49	50,768	30	1	2.0	0.061	0.28
Solanaceae	*Solanum lycopersicum* L. var. *lycopersicum*-1	Miyako	10	3,226	0	0	0.0	0.0	
Solanaceae	*Solanum lycopersicum* L. var. *lycopersicum*-1	Okinawa	33	8,249	17	5	15.2	0.53	
Solanaceae	*Solanum lycopersicum* L. var. *lycopersicum*-1	Yaeyama	28	2,056	2	1	3.6	0.45	
Solanaceae	*Solanum lycopersicum* L. var. *lycopersicum*-2	Miyako	7	9,262	0	0	0.0	0.0	0.10
Solanaceae	*Solanum lycopersicum* L. var. *lycopersicum*-2	Okinawa	5	3,693	0	0	0.0	0.0	
Solanaceae	*Solanum lycopersicum* L. var. *lycopersicum*-2	Yaeyama	56	16,782	1	1	1.8	0.12	
Solanaceae	*Solanum melongena* L.	Amami	45	7,557	0	0	0.0	0.0	0.014
Solanaceae	*Solanum melongena* L.	Miyako	6	915	0	0	0.0	0.0	
Solanaceae	*Solanum melongena* L.	Okinawa	7	1,416	1	1	14.3	0.15	
Solanaceae	*Solanum melongena* L.	Yaeyama	15	155	0	0	0.0	0.0	

Notes: [1]Data sources, by Island, are as follows: Amami Islands:[10–18]. Kume Island:[19]. Miyako Islands:[20–29]. Okinawa Islands:[26,27,29–38]. Yaeyama Islands:[26,27,29,37–42]. [2]Average presented is weighted by the number of collections in each of the islands. Listed below is the calculation used to get the overall average infestation rate for *Benincasa hispida*, to provide an example of the method of calculation of the weighted averages: Overall average% = $(0.034 \times 13 + 38.1 \times 3 + 0.0 \times 2 + 12.2 \times 21 + 17.8 \times 6)/45 = 10.6\%$.

Table 4. Fruits collected in the Southwestern Islands of Japan for which no infestation was found before initiation of suppression activities leading to melon fly eradication. Data taken from publications of Japanese public institutions, in which collection data are presented by Island by date.[1]

FAMILY	SCIENTIFIC NAME	ISLAND	TOTAL NO. OF COLLECTIONS	TOTAL NO. OF FRUITS COLLECTED	COLLECTIONS WITH *B. cucurbitae* INFESTATION		AVERAGE *B. cucurbitae* % INFESTATION
					NO.	%	
Anacardiaceae	*Mangifera indica* L.	Okinawa	1	2	0	0.0	0.0
		Yaeyama	4	122	0	0.0	0.0
Cucurbitaceae	*Cucumis maderaspatana* L.	Okinawa	1	450	0	0.0	0.0
		Yaeyama	2	48	0	0.0	0.0
Fabaceae	*Phaseolus vulgaris* L.	Amami	8	9,537	0	0.0	0.0
		Okinawa	3	261	0	0.0	0.0
Malvaceae	*Abelmoschus esculentus* (L.) Moench	Yaeyama	1	67	0	0.0	0.0
Moraceae	*Ficus thonningii* Blume	Miyako	3	950	0	0.0	0.0
Passifloraceae	*Passiflora edulis* Sims	Yaeyama	1	13	0	0.0	0.0
Solanaceae	*Capsicum annuum* L. cv. *Conoides*	Yaeyama	2	21	0	0.0	0.0
Solanaceae	*Capsicum annuum* cv. *Glossum-2*	Okinawa	1	45	0	0.0	0.0
		Yaeyama	10	1,194	0	0.0	0.0
Solanaceae	*Capsicum annuum* L. cv. *Parvo-acuminatum*	Yaeyama	1	9	0	0.0	0.0
Solanaceae	*Capsicum frutescens L.*	Yaeyama	33	17,247	0	0.0	0.0
Solanaceae	*Solanum capsicoides* All.	Yaeyama	15	664	0	0.0	0.0
Solanaceae	*Solanum mammosum* L.	Yaeyama	4	83	0	0.0	0.0
Solanaceae	*Solanum seaworthianum* Andrews	Okinawa	2	110	0	0.0	0.0

Notes: [1]Data sources, by Island, are the same as listed in Footnote number one of Table 3 above.

"Ki-karasuuri" (*T. kirilowii*) versus ケカラスウリ "Ke-karasuuri" (*T. ovigera*). Because of the identity question, we have not included these collection results in the summary data presented in Table 3.

Of the plant species listed from which no *B. cucurbitae* infestation was found (Table 4), infestation has previously been reported by other authors for most of the species. No record of *B. cucurbitae* infestation has been reported elsewhere for only three of the listed species: *Ficus thonningii* Blume (Moraceae), *Solanum capsicoides* All., and *S. mammosum* L. For most of the fruits collected where no infestation was found, fruit collection numbers were not high (under 1,000 total), with the exception of *Phaseolus vulgaris* L. (9,537) and *Capsicum frutescens* L. (17,247). It may be that low-level infestation could have been found in these plant species also if collection numbers had been considerably increased, because all three species are fairly closely related to plant species in which infestation has been reported.

Considering that melon fly infestation can lead to significant crop loss and can necessitate the development of postharvest quarantine treatments to permit exportation of melon fly susceptible crops out of a place of production, the eradication of melon fly throughout the Southwestern Islands of Japan gave a major positive impact to the production of the fly-susceptible crops. This impact, though, was achieved as a result of considerable financial and labor investment. The eradication program was achieved through the application of SIT. An initial step for this was to reduce wild fly populations in order that the released sterile fly numbers significantly exceeded wild fly population numbers. Wild fly population suppression was achieved through the use of male annihilation (traps incorporating a male lure and a toxicant) and protein bait sprays. Facilities for mass rearing of melon flies for sterile fly release were constructed with fly production ramped up to as high as 200 million flies per week. Produced flies then had to be irradiated and dispersed throughout the Southwestern Islands. Ongoing evaluation of the effectiveness of the sterile fly releases also had to be implemented through trapping assessment of sterile versus wild fly numbers, assessing the level of infestation of melon fly-susceptible fruits, and assessing the hatchability of eggs produced by wild female melon flies.[3] Clearly, considerable effort was exerted; but considerable benefit was achieved. Now, as long as there is no reinvasion by melon fly, there is one less pest problem to which growers must attend.

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Author Contributions

Conceived and designed the experiments: GM, TT. Analyzed the data: GM. Wrote the first draft of the manuscript: GM. Contributed to the writing of the manuscript: GM, TT. Agree with manuscript results and conclusions: GM, TT. Jointly developed the structure and arguments for the paper: GM, TT. Made critical revisions and approved final version: GM, TT. All authors reviewed and approved of the final manuscript.

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Note 1: Islands from which melon fly host infestation data was obtained are indicated within brackets at the end of publication citations: Amami-Oshima Islands (A); Kume Island (K); Okinawa Islands (O); Miyako Islands (M); Okierabu Island (Ok); Tokunoshima Island (T); Yaeyama Islands (Ya); and Yoron Island (Yo). Okierabu Island, Tokunoshima Island, and Yoron Island data are included in the Amami-oshima Island summaries.

Note 2: For references to government publications, which were published in Japanese, the actual Japanese language citation is provided along with an informal English translation, in order to provide an understanding of the nature of the publication for those who do not read Japanese, as well as the actual publication name.

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