Populations of *Bactrocera cucurbitae* (Diptera: Tephritidae) and Its Parasitoid, *Psyttalia fletcheri* (Hymenoptera: Braconidae) in *Coccinia grandis* (Cucurbitaceae) or Ivy Gourd on the Island of Hawaii

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Abstract. The melon fly, *Bactrocera cucurbitae* (Coquillett), readily lays eggs and develops in ivy or scarlet-fruited gourd, *Coccinia grandis* (L.). This plant has become naturalized in Hawaii where it is considered a noxious weed. We sampled *C. grandis* over a two-year period from several locations in the Kona region of Hawaii Island. In 1993 and 1994, average numbers of 500 to more than 800 adult melon flies per kg of fruit were recovered indicating that *C. grandis* is an important contributor to this pest's population. Natural parasitism of melon flies by the introduced braconid wasp, *Psyttalia fletcheri* (Silvestri), averaged 5.5 % during the two-year study. Less than 1.0% of the fruit was infested by the oriental fruit fly, *B. dorsalis* (Hendel), and the Mediterranean fruit fly, *Ceratitis capitata* (Weidemann).

Ivy or scarlet-fruited gourd, *Coccinia grandis* (L.) Voigt (Cucurbitaceae), is native to Africa, Asia and Australia (Telford 1990). It has become naturalized in Hawaii, where it is considered a noxious weed and is a target for biological control (Obrien & Pakaluk 1998). The Hawaii State Department of Agriculture has a program to control this pest (for more information, see www.hear.org). Ivy gourd occurs in Hawaii on the islands of Oahu, Hawaii, Maui, and Kauai, but is most widespread on Oahu and the leeward or Kona side of Hawaii Island, specifically to the area around Kailua-Kona. It is an excellent host for the melon fly, *Bactrocera cucurbitae* (Coquillett), and is likely to become a major reservoir for this pest (Uchida et al. 1990). It is a perennial climbing vine with a tuberous rootstock producing annual stems up to several meters long and grows to cover fences, trees, power lines, and abandoned equipment or buildings. The main stems may be 5-8 cm in diameter at ground level and the plants start new growth rapidly following rainfall. Fruits are green with longitudinal white stripes when immature, but change to a scarlet red at maturity. They are 25–60 mm long and 15–30 mm in diameter (Telford 1990).

The melon fly is one of the four economically important tephritid fruit flies in Hawaii and is a threat to establish in California and other areas of U.S.A. (Carey and Dowell 1989, Cunningham et al. 1990). It is a serious pest of crop and garden plants such as melons, pumpkins, squashes, cucumbers, peppers, beans and tomatoes (Back and Pemberton 1917) and limits the commercial production of some of these crops. The presence of large populations of melon fly in Hawaii (Harris et al. 1986; Vargas et al. 1989, 1990) and the possibility of its introduction to the mainland U.S.A., make it necessary to maintain quarantine programs and to develop fruit and vegetable disinfestation technology against this species.

Nishida (1955) listed eight species of introduced parasitoids on melon fly in Hawaii. Only the braconid wasp *Psyttalia fletcheri* (Silvestri) is an important biological control agent. Parasitism of melon fly by *P. fletcheri* in wild bitter melon, *Momordica charantia* L., was reported to be 86 –96% in 1918 (Willard 1920) and 20 – 50% in the 1950s (Newell et

al. 1952, Nishida 1955, Bess et al. 1961). In commercial crops, parasitism reached 7- 29.8% in 1918 and 0 – 15.6% in 1951. The difference was thought to reflect the smaller size (£ 30-mm diam.) of the fruits of the wild form of bitter melon (similar to *C. grandis*), which allows parasitoids to oviposit into the larvae feeding inside the fruit. A more recent study (Purcell and Messing 1996) suggested that parasitism is higher in rotting fruit (cucumber, zucchini, and tomato) on the ground than in commercially ripe fruit.

Information on the importance of *C. grandis* as a melon fly host is needed for biological control programs and in support of possible eradication or IPM programs. Our study was done to further determine the levels of infestation of *C. grandis* by melon flies in the Kona region of Hawaii Island and to determine the natural parasitism levels on melon flies by the parasitoid *P. fletcheri*. We also studied the variation in numbers of flies and parasitoids per fruit between collection sites and between fruit heights on the vines.

Materials and Methods

Samples of *C. grandis* fruit were collected biweekly in 1993, and weekly in 1994 near Kailua-Kona, Hawaii. Two samples were collected in 1992, one each in November and December. Mature red fruit were collected whenever possible, but when no fully mature fruit were present, fruit with any red color were collected. Likewise, whole undamaged fruit were collected, but occasionally when fruit was scarce, ones that were one-third or less eaten were taken. Collections of these damaged or partially ripe fruit were infrequent and melon fly larvae were still reared from them.

Sampled fruits from 1993 and 1994 were weighed and held individually in 0.47 liter plastic cups, which were covered with organdy and then capped with clear, vented lids. Individual fruits, except for the 1992 samples, were placed directly on 50 ml of sand that layered (8 ml deep) the bottom of the cups and fly larvae completed development and pupated in or on the sand. After adult flies or parasitoids emerged and died, they were sieved from the sand and identified. For each fruit, we recorded weight and the number of insects reared (fruit fly puparia and adults and parasitoid adults, identified to species).

1992–1993. Samples were collected from five sites ranging from just above sea level to about 200 m. The sites were located along drainages or in areas where water accumulated and represented the typical habitats for *C. grandis* on this island. Site one near Kailua (6 m) and site two near Keauhou (10 m) were selected from many possible locations near sea level along Alii Drive. Site three (170 m) was at the intersection of Kamehameha III and Kuakini (Hwy. 11) and site four (140 m) was along Queen Kaahumanu Highway (Hwy 19) on the Kailua side of the Kuakini junction. Site four was a small area along the edge of a paved highway and some of the vines grew over the surface of the roadside so the fruit was in contact with the hot soil. Site five (200 m) was along Palani Road (Hwy 190) above Kailua.

Fruits were collected from three height ranges on the vines, i.e. £ 0.3, >0.3-1.5, and >1.5-3.0 m above ground. The lower height range (£ 0.3 m) included fruit on the ground below the vines. A few fruit occurred at heights above 3 m on vines that grew up and over trees, but these fruits were not collected because they tended to be few and were not available at all sites. The number of fruit collected at the three height ranges varied with available moisture over time and among sites. Two samples were collected in 1992, one on 24 November and the other on 8 December. The fruit collected on these dates were held collectively, so data on individual fruit were not available. In 1993, collections were made biweekly from 12 January through 2 June, when fruiting ceased at most sites.

1994. Fruit were collected at eight sites near Kailua-Kona from 1 March (when fruiting started) to 12 May (when fruiting stopped at most sites). Sites one, two, three, and four (3–

10 m) were selected from areas along Alii Drive between Kailua and Keauhou. Sites five (140 m) and six (140 m) were along the roadside of Queen Kaahumanu (Hwy 19) between the Kuakini junction and Kailua. Site seven (30 m) was at the junction of Hwy 19 and Hwy 190 and site 8 (200 m) was above Kailua along Hwy 190 (site five in 1993). The sites varied in shape, e.g. along fencerows or over small stands of trees or on trees and bushes along the roadside. Fruit were held individually, but were not divided by height as was done in 1993.

For data with a normal distribution and equal variances, analyses were done by one-way ANOVA and the Tukey Test. When the data was not normally distributed, Kruskal-Wallis Anova on Ranks and Dunn's Method for all pairwise multiple comparison procedures were used (SigmaStat 1995). The relationship between fruit size (weight in grams) and the number of melon fly puparia per fruit was determined by Spearman Rank Order Correlation (SigmaStat 1995). The frequency distributions for the number of melon fly puparia per fruit and the number of *P. fletcheri* per fruit for 1993 and 1994 were compared using the Mann-Whitney Rank Sum Test (SigmaStat 1995). Unless stated otherwise, numbers are presented as the mean and SEM.

Results

1992–93. During 1992, 748 fruit were collected in two samples from which 2,813 melon fly puparia were reared. From these puparia, we reared 1,906 melon fly adults (67.8% emergence) and 145 *P. fletcheri*. Mean parasitism of melon fly puparia was 1.98% in November and 6.3% for the December sample. The number of puparia per kg, when averaged over the five sites, was 83 in November and 425 in December. We also reared 30 oriental fruit flies, *Bactrocera dorsalis* (Hendel) from the fruit, seven of which were parasitized by *Fopius* (=*Biosteres*) *arisanus* (Sonan).

A total of 1,592 *C. grandis* fruit were collected in 1993; of these 618 (38.8%) were infested with 8,350 tephritid puparia. Melon fly puparia were reared from 613 or 38.5% of the total number of fruit. The number of puparia (all species) per fruit (all fruit collected) was 5.2 ± 9.91 (± SD). The 613 infested fruit produced 12.7 ± 11.17 (± SD) melon fly puparia with a maximum of 73 puparia in an individual fruit. Of the 73 melon fly puparia reared from one fruit, 93.1% emerged as adults. Overall, adults emerged from 98.9% of the puparia reared from *C. grandis* in 1993, so puparial mortality was very low. A total of 444 *P. fletcheri* emerged from melon fly puparia reared from 91 infested fruit, an average of 4.8 per fruit. The sex ratio (%:&) of emerged insects was 1.0:1.0 for melon flies and 1.0:1.35 for *P. fletcheri*.

The average weight of the *C. grandis* fruit was 9.5 ± 5.2 g (± SD); the range of weights varied from 0.9 to 26.5 g. The number of puparia reared from individual fruit showed a positive correlation with the weight of the fruit (r_s=0.0967, P<0.001, N=1592). The average yield of melon fly puparia and adults per kg of fruit collected in 1993 was 612.4 and 564.4, respectively.

Fifty-six fruits produced 63 flies of other species in addition to melon flies. Of these 63 tephritid flies, 35 were oriental fruit flies, 27 were Mediterranean fruit flies, *Ceratitis capitata* (Weidemann), and one was *Bactrocera latifrons* (Hendel). All these were reared from fruit collected at or near sea level (sites 1 and 2).

Results by site. Fruit weight and infestation by melon flies varied significantly by site (Table 1). More fruit were collected from the sites (1 and 2) near sea level than those at higher elevations. The percentage of the fruit infested varied significantly among the sites (H = 21.5373, d.f. = 4, P = 0.00024) and was lowest at site four (19.2), where some of the fruit was exposed to the hot soil and gravel along the roadside. Likewise, the percentage of puparia parasitized by *P. fletcheri* was lowest at site four (Table 1). There were significant

Table 1. Number of *C. grandis* fruit collected in 1993, percentage infested by melon flies, number of melon fly puparia per fruit and percentage of puparia parasitized.

Site[1]	No. fruit	Fruit wt (g)	Fruit infested (%)	Puparia per fruit	Puparia per infested fruit	Parasitism[2] (%)
1	613	12.3 ± 0.71b	30.2 ± 4.13ab	4.2 ± 0.72a	14.6 ± 1.95ab	3.3 ± 1.1
2	420	7.8 ± 0.41ac	44.6 ± 4.67a	5.7 ± 0.90ab	11.9 ± 1.10a	6.4 ± 2.1
3	112	13.8 ± 2.53b	58.5 ± 8.26a	17.6 ± 4.01b	28.5 ± 4.41b	9.3 ± 3.6
4	172	10.0 ± 1.08bc	19.2 ± 4.65b	4.3 ± 1.62a	12.4 ± 2.88a	0.2 ± 0.2
5	275	5.4 ± 0.036a	44.1 ± 6.34a	4.5 ± 0.84a	9.7 ± 0.99a	4.6 ± 1.1

Mean ± SEM for all collections over all dates (11) and for all heights (3); n = 33.
Numbers in columns followed by different letters are significantly different (P < 0.05).
[1]Sites 1 and 2 were near sea level, site 3 was 170 m, site 4 was 140 m and site 5 was at 200 m above sea level.
[2]There were no significant differences among the sites in percent parasitism by *Psytallia fletcheri*.

differences in parasitism among the sites (H = 10.3227, d.f. = 4, P = 0.03533), but differences between the sites were not significant (P > 0.05). Maximum parasitism for a given site (5) and date (12 January) was 33.3%.

Results by height. More fruit were collected at 0-0.3 m (506) and at 0.3-1.5 m (718) than at 1.5-3.0 m (367). There were significant differences in percentage infestation among the heights (F = 3.8886, d.f. = 2, 30, P = 0.0315). Infestation of fruit by melon flies was greater at 0.3-1.5 m and 1.5-3.0 m (45.0 ± 0.05% and 42.5 ± 0.06%) than at 0-0.3 m (27.6 ± 0.05%), but only the difference between 0-0.3 m and 0.3-1.5 m was significant (q = 3.6417, P = 0.0393). Despite differences in infestation of fruit, the average number of puparia produced per infested fruit was similar (12.0, 12.8, and 12.8) for all three heights (H = 1.7543, d.f. = 2, P = 0.4159). Parasitism of melon fly puparia by *P. fletcheri* averaged 3.6 ± 1.9% at height one, 5.4 ± 1.9% at height two, and 6.1 ± 1.9% at height three, but did not differ significantly (H = 4.7257, d.f. = 2, P = 0.0941).

1994. A total of 3,851 *C. grandis* fruit were collected from the eight sites; melon fly puparia were reared from 1,859 or 48.3% of the fruit (Table 2). Another 0.8% was infested by oriental or Mediterranean fruit flies. A total of 29,241 melon fly puparia were reared from the fruit; 91.5% of these produced adult melon flies and/or *P. fletcheri*. The average number of melon fly adults that emerged per infested fruit was 14.7 ± 11.92 (± SD; range 1-93) and the average number for all fruit collected from all plots was 7.4. A total of 1,913 *P. fletcheri* was reared from 398 fruit for an average of 4.8 ± 4.9 (± SD) parasitoids per fruit producing parasitoids. Thirty-four parasitoids were reared from one fruit infested with 64 melon fly puparia. Site six (site 4 in 1993) with fruit growing on the hot soil had the lowest percentage of infested fruit, number of puparia per fruit, and percentage of puparia parasitized.

Average parasitism levels at the eight sites varied from 1.9 at site six to 10.0 at site four and 10.9% at site three; both sites three and four were ≤10 m above sea level (Table 2). Maximum parasitism for a site (5) and date (21 April) was 27.5% (178 of 647 puparia). Four eulophid parasitoids, *Tetrastichus giffardianus* Silvestri, were reared from one melon fly puparium.

Table 2. Number and weight of *C. grandis* fruit collected in 1994, percentage infested by melon flies, number of melon fly puparia per fruit, and percentage of puparia parasitized.

Site[1]	No. fruit	Fruit wt (g)	Fruit infested (%)	Puparia per fruit	Puparia per infested fruit	Parasitism[2] (%)
1	540	12.2 ± 0.59[a]	39.8 ± 4.69[b]	5.6 ± 0.74[bc]	13.3 ± 0.93[bc]	5.1 ± 1.22[ab]
2	512	8.4 ± 0.56[b]	38.4 ± 4.87[b]	6.6 ± 1.14[bc]	16.1 ± 1.50[ab]	2.6 ± 0.91[ab]
3	580	8.4 ± 0.42[b]	49.3 ± 3.40[ab]	7.3 ± 1.10[b]	14.3 ± 1.64[abc]	10.9 ± 2.05[a]
4	495	7.8 ± 0.30[b]	63.7 ± 6.09[a]	9.7 ± 1.35[ab]	14.8 ± 1.14[abc]	10.0 ± 2.61[a]
5	433	8.8 ± 0.72[b]	41.6 ± 7.30[ab]	7.7 ± 2.05[ab]	16.9 ± 1.76[ab]	6.9 ± 2.61[ab]
6	410	14.7 ± 0.86[a]	11.3 ± 2.94[c]	1.3 ± 0.44[c]	9.1 ± 2.02[c]	1.9 ± 1.18[b]
7	475	6.8 ± 0.67[b]	56.4 ± 4.0[ab]	7.6 ± 1.00[ab]	13.2 ± 1.17[bc]	4.5 ± 0.81[ab]
8	406	7.5 ± 0.66[b]	64.4 ± 6.80[a]	13.7 ± 2.31[a]	19.9 ± 1.45[a]	5.4 ± 1.75[ab]

Different letters following the mean ± SEM in a column indicate a significant difference at P = 0.05 (N=11). Percentage parasitism by *Psytallia fletcheri* was analyzed by Kruskal-Wallis One Way ANOVA on Ranks and all pairwise comparisons by Dunn's method (SigmaStat 1995); all other data were analyzed by one-way ANOVA and the Tukey test.
[1]Sites 1–4 were near sea level (≤10 m), 5 and 6 were 140 m, 7 was 30 m, and 8 was at 200 m above sea level.

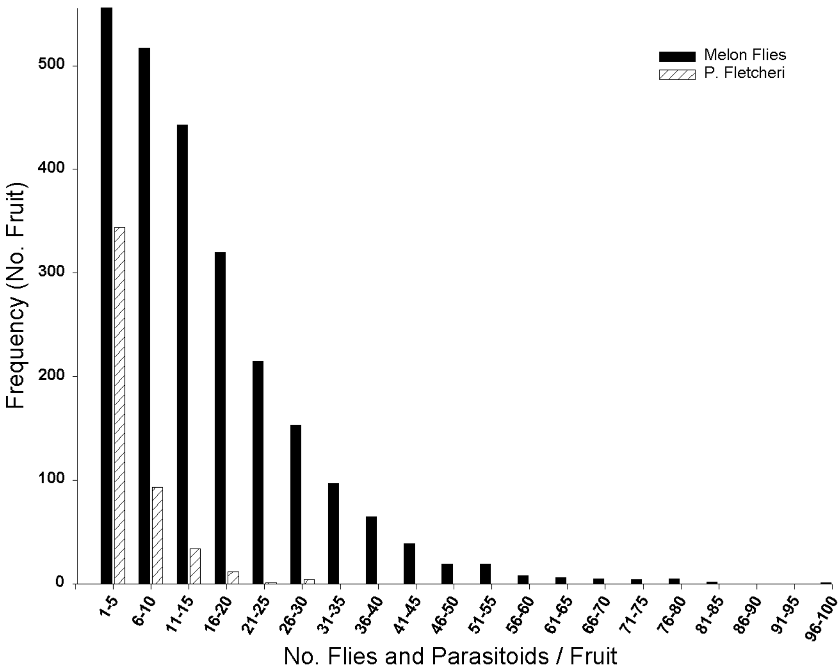
The frequency distributions of the number of melon fly puparia per infested fruit and the number of *P. fletcheri* per fruit producing parasitoids were similar in 1993 and 1994 (T = 425.5, N = 21, P = 0.5212 and T = 677.0, N = 26, P = 0.88333, respectively), so the data were combined (Fig. 1). Approximately 74% of the infested fruit produced 1-20 melon fly puparia. The number of *P. fletcheri* per fruit, from which the parasitoid was reared, varied from 1 to 34, but most fruit produced five or fewer parasitoids.

The average weight of the fruit was 9.4 ± 4.6 g, but the weight of individual fruit varied from 0.5 to 26.9 g. The number of puparia reared from individual fruit did not increase consistently with the size (weight) of the fruit in 1994; there was no significant correlation between fruit size (weight) and the number of puparia reared from the fruit (r_s = 0.0245, N = 3851, P = 0.128). Because of the low parasitism levels and lack of significant differences in rates, we could not show an association between fruit size and parasitism. The number of melon fly puparia and adults obtained per kg of fruit collected was 806.1 and 738.2, respectively.

Discussion

Our data extend the information from the limited collections of Uchida et al. (1990) on Hawaii Island. Their collections were made mostly on the island of Oahu, where this plant is more widespread. All our collections were from Hawaii Island, where *C. grandis* is limited to the leeward or drier side of the island. On both islands it can be found in areas where vegetable hosts are grown commercially and near backyard gardens. Additionally, it can serve as a host for oriental fruit flies and Mediterranean fruit flies. *Bactrocera latifrons* has

Figure 1. Frequency distribution of the number of melon flies and *P. fletcheri* reared per *C. grandis* fruit in 1993–94.



been reared from *C. grandis* (Liquido et al. 1994), however we reared only one adult from our collections.

Uchida et al. (1990) reared an average of 7.7 melon flies per fruit from preliminary collections on Oahu in 1988. From Dec. 1988 to Apr. 1989, they collected 218 fruit in 10 collections from four locations on Oahu and reared an average of 95.5 melon flies per kg fruit (range = 0 to 254.6). They collected 43 fruit from Kailua (sea level) and Kalaoa (245 m) on Hawaii Island to show the distribution of *C. grandis*, but did not obtain any flies. In a study of the host plants of *B. latifrons*, Liquido et al. (1994) collected 313 *C. grandis* fruits near Kailua in four collections over a 2-year period. From these they reared about 144.5 melon fly puparia per kg of fruit. We collected a total of 5,442 *C. grandis* fruit and reared 564.4 and 738.2 adult melon flies per kg of fruit in 1993 and 1994, respectively. There was considerable variation in our data over dates and sites showing that collections should be made over several dates and at several sites to get a good estimate of infestation. Locations with more consistent soil moisture, e.g. sites one and two in 1993, produced more fruit for a longer time.

The weedy form of *M. charantia* is considered the most important wild cucurbit host plant of melon flies in Hawaii. Average numbers of adult flies of 370 per kg of fruit on Kauai (Harris et al. 1986), 270 per kg on Maui, and 180 per kg on Hawaii Island (Liquido et al. 1990) have been reared from this host. Our numbers from 1993-94 show that *C. grandis*

produces more flies per kilogram of fruit than are reared from *M. charantia* and, where it is established, it is a major contributor to melon fly populations. However, *M. charantia* is more widespread across the islands and probably remains the most important non-cultivated host for this reason.

Although natural parasitism of melon fly remained low, further evaluation of the potential of *P. fletcheri* (i.e., augmentative releases) to be an effective part of an IPM program for melon fly control should be done. This is especially true as *P. fletcheri* was the only parasitoid reared in any numbers. There is also a need for a concentrated effort to search for additional, and more effective, parasitoids of melon flies.

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