# Biology and Host Specificity of *Melittia oedipus* (Lepidoptera: Sesiidae), a Biological Control Agent of *Coccinia grandis* (Cucurbitaceae)

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**Abstract.** A discussion of the host range testing and a brief description of the biology of *Melittia oedipus* Oberthür (Lepidoptera: Sesiidae) are presented. This clearwing moth was introduced into Hawaii from Kenya to combat ivy gourd, *Coccinia grandis* (L.) Voigt (Cucurbitaceae), a noxious vine of East African origin. Host range testing consisted of two parts: exposure of potted plants to adult *M. oedipus* to test oviposition preference, and placement of fertile eggs or neonate larvae on plants to test larval feeding and development. Test results indicated that *M. oedipus* is specific to ivy gourd. In larval feeding tests, a very small number of adults completed development on cucumber (*Cucumis sativus*) vines. However, oviposition choice tests showed that under field conditions, *M. oedipus* females would be highly unlikely to lay eggs on cucumber. Since *M. oedipus* was released on the island of Oahu in 1996, there has been no record of attack on cucumber or any other nontarget plant.

**Key words:** biological control, *Coccinia grandis*, Cucurbitaceae, *Melittia oedipus*, Sesiidae

## Introduction

Ivy gourd, *Coccinia grandis* (L.) Voigt (Cucurbitaceae), is a perennial vine that has invaded lowland areas of the Hawaiian Islands in recent years. It is native to Africa but also occurs wild in the Indo-Malayan region (Singh 1990) and is naturalized in parts of Australia, the Caribbean, the southern United States, and several Pacific Islands, including Hawaii (Telford 1990, Linney 1986). According to Dr. Charles Jeffrey of the Royal Botanic Gardens in London, *C. grandis* is native to north central East Africa and perhaps Arabia. He believes it moved into Asia in trade several hundred years ago (R. Burkhart, pers. comm.). The other 29 species of *Coccinia* are confined exclusively to tropical Africa (Singh 1990). It is believed that Southeast Asian immigrants, who use the plant for food and medicinal purposes (Ramachandran and Subramaniam 1983), introduced it into Hawaii during the 1960s. Since first collected in 1968 in the Punchbowl area of Honolulu (Nagata 1988), it has spread extensively in many areas on the island of Oahu and on the Kona coast of the island of Hawaii, from sea level to ca. 245 m elevation (Uchida et al. 1990). Small populations are now also found on Maui and Kauai.

Ivy gourd frequently blankets trees, understory vegetation, fences and other man-made structures in residential neighborhoods and agricultural areas. In addition to killing underlying vegetation, the heavy vines hanging from telephone and electrical wires have created maintenance problems for utility companies. The fruits of ivy gourd serve as a major reservoir for the melon fly, *Bactrocera cucurbitae* (Coquillet) (Uchida et al. 1990), which attacks economically important food crops and restricts Hawaii's ability to export produce. For the above reasons, the Hawaii Department of Agriculture (HDOA) declared ivy gourd a noxious weed and initiated a program to control it.

From May to September 1992, Robert Burkhart, exploratory entomologist for HDOA, conducted a search for natural enemies of ivy gourd in Kenya, East Africa, in hopes of finding effective biocontrol agents. Ivy gourd was found primarily along the Indian Ocean coastal region south of Mombasa and around the inland Lake Victoria basin. Both areas have a modified equatorial climate with high daytime temperatures and humidity. Some rainfall occurs throughout the year along the coast, with maximum amounts in April/May and October/November.

Burkhart collected over 30 species of insects that fed on ivy gourd. A sesiid stem-boring moth was found to be one of the most common and damaging insects. He noted that ivy gourd frequently grows near vegetable crops on small farms in Kenya, but found no apparent crossover of the sesiid to other cucurbit species when examining the stems of many wild and cultivated cucurbits (R. Burkhart, pers. comm.). Preliminary host range tests, using plants grown from seeds of the most economically important cucurbit species brought from Hawaii to Africa, were conducted at a temporary base set up at Diani Beach on the coast south of Mombasa, and a colony of the moth, collected at Diani Beach and nearby environs in May and June 1992, was sent back to the HDOA quarantine facility for further testing.

The moth was subsequently identified and redescribed by Eichlin (1995) as *Melittia oedipus* Oberthür. This species was originally named and described by Oberthür (1878) (cited in Eichlin 1995) from specimens collected in Zanzibar. Its host plant was previously unknown. Members of the genus *Melittia* Hübner are worldwide in distribution, and all known species are obligate internal feeders in the vines or underground tuberous roots of plants in the family Cucurbitaceae (Eichlin 1975, Eichlin and Duckworth 1988, Engelhardt 1946). Most sesiid species are known to have rather narrow host preferences, with species restricted to a single plant genus or plant family (Brown and Mizell 1993). This paper reports on the host specificity studies and biology of *M. oedipus* in Hawaii.

## Materials and Methods

**Oviposition choice tests.** Nineteen species of Cucurbitaceae, including all 14 cultivated and naturalized species in Hawaii, four native species of *Sicyos*, and ivy gourd, were subjected to oviposition and larval feeding tests in the HDOA quarantine facility (Table 1). Nine species in other families were also tested, including taxonomically unrelated vines that often grow adjacent to ivy gourd, and several species in families that, along with Cucurbitaceae, belong to the Order Violales (Table 2).

Oviposition choice tests were conducted in silkscreen cages (91 x 46 x 64 cm) with plexiglass viewing panels on one side. For each trial, 25 < one-day-old females and an equal or greater number of newly emerged males were placed in a cage containing a potted test plant and a potted ivy gourd vine for seven days. Vines were 60 to 90 cm in length and were usually flowering. Honey and sugar water were provided as food for the moths. Within-cage temperatures averaged 22 ± 1°C at night and 34 ± 2°C during the day with a photoperiod of 13:11 (L:D). Cages were placed in the southwest corner of the laboratory where they received maximum sunlight during the day, as natural light stimulated mating and oviposition. Tests were replicated five times for most of the cucurbits and a lesser number for non-cucurbits, as noted in Tables 1 and 2. At the end of each trial, all eggs were counted to determine the number laid on the test plant, on ivy gourd, and on cage surfaces.

An additional five replications were done with potted cucumber and ivy gourd plants arranged in random patterns inside a lumite field cage (1.83 x 1.83 x 1.83 m), set up within the quarantine insectary, in order to investigate the possible influence of cage size on oviposition choice.

**Oviposition no-choice tests.** One potted ivy gourd and one potted cucumber were each confined in separate small cages (45.7 x 45.7 x 63.5 cm) with five female and eight male adult moths. Tests were replicated nine times. After all females had died, the number of eggs laid on each plant and on all cage surfaces was counted. Females were dissected to verify mating, as unmated females lay few or no eggs.

**Larval feeding tests.** All eggs deposited on plants during oviposition tests were left in place, and additional eggs were transferred from ivy gourd to nontarget plants, if necessary, to ensure a minimum of 30 eggs per replication on each test plant. Egg hatching was verified to be sure each plant was exposed to viable larvae. In addition, thirty neonate larvae were transferred from ivy gourd to cut or potted non-cucurbit plant species not subjected to oviposition choice tests. Three replications were done for each of the following species: Apiaceae (*Centella asiatica, Daucus carota*), Brassicaceae (*Brassica oleracea*), Fabaceae (*Phaseolus vulgaris*), Solanaceae (*Lycopersicon esculentum, Solanum melongena*), Flacourtiaceae (**Xylosma hawaiiense*), and Violaceae (**Isodendrion laurifolium, *Viola chmissoniana* subsp. *tracheliifolia*) (*endemic Hawaiian species). All trials were continued until no living larvae remained.

**Life history.** Mating behavior was observed in the laboratory during colony maintenance from 1993 to 1996, as well as in the field, following release on Oahu in 1996. Field-collected larvae, pupae and eggs were returned to the laboratory for examination and to hold for the possible emergence of parasitoids. The length of the various life stages was noted during laboratory studies. Cucumber and *Sicyos pachycarpus* vines were examined approximately twice a year following release of *M. oedipus* to check for possible crossover from ivy gourd. Unmated laboratory-reared females were dissected to determine the average number of eggs carried per female.

## Results

**Oviposition choice tests.** Results of the oviposition choice tests are summarized in Tables 1 and 2. In oviposition choice tests that examined the effect of cage size on oviposition behavior, the number of eggs laid on cucumber in small cage trials was six times greater than the number laid in large cage trials (Table 1). However, these differences were statistically insignificant ($t$ = 1.3339, df = 8, P = 0.2189), as the numbers involved were so extremely low. No eggs were laid on cucumber in three of the five small cage trials and none was laid on cucumber in four of the five large cage trials.

**Oviposition no-choice tests.** In the nine small-cage oviposition no-choice tests, a mean of 10.9 ± 9.6 (4.5%) eggs were laid on cucumber and 231.8 ± 90.4 (95.5%) were laid on cage surfaces. In the control cages, which contained only ivy gourd, 423.2 ± 237.5 (84.9%) were laid on ivy gourd and 75.0 ± 52.6 (15.1%) were laid on cage surfaces.

Dissection of the five females placed in each cage revealed that 3.7 ± 1.1 of the females confined with cucumber plants were mated versus 3.4 ± 1.1 of those confined with ivy gourd. Despite the slightly higher number of mated females in the cages containing cucumber, more than twice as many total eggs were laid in cages with ivy gourd. Dissection of mated females at the end of each trial confirmed that they were retaining eggs when ivy gourd was not available.

**Larval feeding tests.** Results of larval feeding tests are given in Tables 1 and 2. Larvae were unable to develop on any test plant other than cucumber. The few adult *M. oedipus* produced on cucumber vines were smaller and took an average of two weeks longer to develop than those on ivy gourd. No mating or oviposition occurred when these adults were placed with new cucumber plants. No feeding occurred on any plants outside the family Cucurbitaceae.

Table 1. Results of *Melittia oedipus* oviposition choice and feeding tests with ivy gourd (*Coccinia grandis*: Cucurbitaceae/Benincaseae) and other species in the family Cucurbitaceae[1]

| Tribe/Species | Common name | Replications | No. of eggs found on [mean ± SD (% total)] Test plant | Ivy gourd | Cage | Larval feeding[2] |
|---|---|---|---|---|---|---|
| Benincaseae | | | | | | |
| *Benincasa hispida* | wax gourd | 5 | 8.8 ± 11.9 (0.5) | 1382.6 ± 783.4 (85.6) | 223.6 ± 146.3 (13.9) | 1 |
| *Citrullus lanatus* | watermelon | 5 | 4.0 ± 5.1 (0.3) | 961.4 ± 728.7 (82.5) | 199.8 ± 164.0 (17.2) | 0 |
| *Lagenaria siceraria* | bottle gourd, ipu | 5 | 0.4 ± 0.5 (0.04) | 802.0 ± 413.5 (79.98) | 200.4 ± 80.3 (19.98) | 0 |
| *Luffa acutangula* | seequa | 5 | 19.8 ± 16.2 (1.9) | 875.2 ± 374.8 (85.3) | 131.4 ± 92.1 (12.8) | 0 |
| *L. aegyptiaca* | sponge gourd | 5 | 12.7 ± 10.6 (1.0) | 1060.3 ± 60.6 (79.8) | 255.3 ± 86.1 (19.2) | 0 |
| Cucurbiteae | | | | | | |
| *Cucurbita maxima* | hubbard squash | 5 | 7.8 ± 9.1 (0.4) | 1579.0 ± 905.8 (80.1) | 384.8 ± 265.2 (19.5) | 1 |
| *C. moschata* | butternut squash | 5 | 4.4 ± 5.6 (0.2) | 1779.2 ± 850.9 (81.0) | 414.0 ± 215.5 (18.8) | 1 |
| *C.maxima x C.moschata* | kabocha squash | 1 | 0 ± 0 | 1228.0 ± 0 (93.1) | 91.0 ± 0 ( 6.9) | 1 |
| *C. pepo* | summer crookneck | 1 | 0 ± 0 | 2445.0 ± 0 (87.6) | 345.0 ± 0 (12.4) | 1 |
| | Conn. field pumpkin | 2 | 1.5 ± 2.1 (0.1) | 1215.0 ± 131.5 (82.8) | 250.5 ± 105.4 (17.1) | 1 |
| | zucchini | 5 | 7.8 ± 11.9 (0.4) | 1431.4 ± 391.2 (81.7) | 311.8 ± 121.1 (17.8) | 1 |
| Joliffieae | | | | | | |
| *Momordica charantia* | bitter melon | 5 | 8.0 ± 11.0 (0.5) | 1366.0 ± 534.2 (78.5) | 364.4 ± 133.3 (21.0) | 0 |
| Melothrieae | | | | | | |
| *Cucumis dipsaceus* | wild cucumber | 3 | 1.0 ± 1.0 (0.05) | 1579.3 ± 190.5 (86.29) | 250.0 ± 149.3 (13.66) | 0 |
| *C. melo* v. conomon | oriental pickling melon | 5 | 6.4 ± 5.4 (0.3) | 1608.2 ± 462.2 (81.6) | 356.2 ± 131.1 (18.1) | 2 |
| *C. melo* v. inodorus | honeydew melon | 3 | 3.7 ± 2.5 (0.2) | 1518.7 ± 435.1 (83.7) | 292.0 ± 80.0 (16.1) | 2 |
| *C. melo* v. reticulatus | cantaloupe | 5 | 6.8 ± 6.3 (0.4) | 1585.6 ± 823.3 (87.7) | 215.2 ± 89.6 (11.9) | 2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| *C. sativus* | cucumber | 5[3] | 2.6 ± 3.6 (0.2) | 947.0 ± 449.5 (87.4) | 134.2 ± 91.9 (12.4) | 3 |
| | cucumber | 5[4] | 0.4 ± 0.9 (0.03) | 1218.0 ± 402.7 (88.76) | 153.8 ± 55.9 (11.21) | 3 |
| Sicyeae | | | | | | |
| *Sechium edule* | chayote | 5 | 33.8 ± 23.2 (1.9) | 1409.8 ± 357.8 (78.7) | 347.4 ± 169.3 (19.4) | 1 |
| *Sicyos erostratus* | endemic cucurbit | 5 | 10.8 ± 2.9 (0.5) | 1633.8 ± 803.0 (84.8) | 282.8 ± 233.7 (14.7) | 1 |
| *S. hispidus* | endemic cucurbit | 1 | 2.0 ± 0 (0.2) | 680.0 ± 0 (68.2) | 315.0 ± 0 (31.6) | 1 |
| *S. pachycarpus* | endemic cucurbit | 3 | 4.0 ± 2.6 (0.4) | 893.0 ± 198.6 (83.5) | 172.3 ± 87.4 (16.1) | 1 |
| *S. waimanaloensis* | endemic cucurbit | 3 | 20.7 ± 17.0 (1.2) | 1374.7 ± 519.1 (79.0) | 344.7 ± 330.3 (19.8) | 1 |
| Trichosantheae | | | | | | |
| *Trichosanthes anguina* | snake gourd | 4 | 0 ± 0 | 2283.0 ± 1098.0 (88.6) | 293.3 ± 125.8 (11.4) | 0 |

[1]25♀/25♂ *M. oedipus* adults placed with one potted test plant and one potted ivy gourd in 91.4. x 45.7 x 63.5 cm cage for seven days.
[2]0 = no feeding; 1 = exploratory feeding by 1st instar larvae only; 2 = survival to 2nd instar only; 3 ≤ 2% of larvae completed development; no F2 generation produced.
[3]Oviposition choice tests conducted in 91.4 x 45.7 x 63.5 cm cage.
[4]Oviposition choice tests conducted in 1.83 x 1.83 x 1.83 m cage.

Table 2. Results of *Melittia oedipus* oviposition choice and feeding tests with ivy gourd, *Coccinia grandis* (Violales: Cucurbitaceae) and non-cucurbit species[1].

| Order / Family / Species | Common name | Replications | No. of eggs found on [mean ± SD (% total)] Test plant | Ivy gourd | Cage | Larval feeding[2] |
|---|---|---|---|---|---|---|
| Aristolochiales | | | | | | |
| Aristolochiaceae | | | | | | |
| *Aristolochia littoralis* | calico flower | 2 | 0.5 ± 0.7 (.02) | 1935.0 ± 586.9 (88.24) | 257.5 ± 170.4 (11.74) | 0 |
| Begoniales | | | | | | |
| Begoniaceae | | | | | | |
| *Begonia hirtella* | | 3 | 8.3 ± 8.5 (0.4) | 1730.3 ± 329.6 (84.1) | 317.7 ± 52.7 (15.5) | 0 |
| Gentianales | | | | | | |
| Apocynaceae | | | | | | |
| *Alyxia oliviformis* | maile | 1 | 2.0 ± 0 (0.08) | 2201.0 ± 0 (88.97) | 271.0 ± 0 (10.95) | 0 |
| Solanales | | | | | | |
| Convolvulaceae | | | | | | |
| *Merremia tuberosa* | wood rose | 1 | 18.0 ± 0 (1.1) | 1127.0 ± 0 (70.1) | 464.0 ± 0 (28.8) | 0 |
| *Ipomoea obscura* | morning glory | 1 | 0 ± 0 | 1008.0 ± 0 (83.4) | 200.0 ± 0 (16.6) | 0 |
| Violales | | | | | | |
| Caricacea | | | | | | |
| *Carica papaya* | papaya | 3 | 6.3 ± 3.8 (0.4) | 1463.3 ± 436.7 (90.7) | 144.3 ± 31.0 (8.9) | 0 |
| Passifloraceae | | | | | | |
| *Passiflora edulis* | purple passion vine | 3 | 20.3 ± 4.0 (1.4) | 1261.0 ± 340.5 (87.4) | 161.0 ± 107.2 (11.2) | 0 |
| Turneraceae | | | | | | |
| *Turnera ulmifolia* | yellow alder | 2 | 0.5 ± 0.7 (0.03) | 1503.0 ± 4.2 (86.65) | 231.0 ± 26.9 (13.32) | 0 |
| Violaceae | | | | | | |
| *Viola* sp. | violet | 2 | 7.0 ± 0 (0.4) | 1365.5 ± 85.6 (81.1) | 310.5 ± 10.6 (18.5) | 0 |

[1]25 ♂/25+♀ *M. oedipus* adults placed with one potted test plant and one potted ivy gourd in 91.4 x 45.7 x 63.5 cm cage for seven days.

**Life history.** *Melittia oedipus* is a diurnal species, as is typical for moths in the family Sesiidae. In the laboratory, adults emerged from pupal cases by mid-morning and females began emitting pheromones to attract males as soon as their wings were dried. Mating took place, usually on the day of emergence, in late morning or early afternoon on sunny days and lasted up to two hours. Mating was sometimes delayed for a day or two if the weather was cloudy. Once mated, females began ovipositing within the next half-hour. Eggs were laid individually on all parts of the ivy gourd plant, including leaves, tendrils and stem. Fifty dissected, unmated, laboratory-reared females were found to contain 60–140 eggs (mean: 110 per female). Flight activity, mating, and oviposition did not begin until temperatures reached 25°C, with peak activity occurring between 33–35°C. Eclosion occurred in 11 ± 1 days. Neonate larvae bored into ivy gourd stems either through young growing tips or directly into the thick stems of older vines. Larvae were not found to be cannibalistic and were able to live in close proximity to one another within the thicker stems. Pupation took place within the cut pieces of stem provided for larval development. Adults from the same cohort in laboratory colonies emerged over a period of two to four months following oviposition, with males greatly outnumbering females during the first several days of emergence. The sex ratio was 1:1, and adult life span averaged six days (range: 2–9 days).

Adults are not easily seen in the field, especially on sunny days, due to their rapid and erratic flight pattern, which resembles that of bees. Early in the morning, late in the afternoon, or on cloudy days, they may sometimes be found resting on ivy gourd leaves. When virgin females are taken into the field, males in the area appear in as little as one to five minutes. It is unknown from what distance *M. oedipus* males will be attracted, but it has been reported that other species of clearwing males can sometimes detect females as far away as 1.4 to 2.8 km from the source (Brown and Mizell 1993). Eggs have been found on thick primary vines, from ground to tree top level in vines that have been pulled down. They have not been seen on leaves, though it is possible they were missed due to the thick vegetation. Newly laid eggs have been found adjacent to portions of vine already infested with *M. oedipus* larvae or near sites with empty pupal cases. A range of different larval instars may be found together in close proximity in the same vine. This phenomenon was also noticed in the native land (R. Burkhart, pers. comm.). Fully developed larvae and pupae have been found in all sizes of vines ranging from 0.5 to 9 cm in diameter. In narrow vines (0.5–1.5 cm), the larva causes a gall-like thickening (not a true gall), which may be easily seen. In thicker vines, it is much more difficult to determine if the vine is infested, and the only clue may be a small hole in the vine or sometimes extruded frass which has not yet been washed away by rain. After adults have emerged, the empty pupal exuviae are left protruding from the vines. Adults of both sexes have been observed feeding on nectar in the flowers of the weeds *Justicia betonica* (Acanthaceae) and *Chamaesyce hypericifolia* (Euphorbiaceae) growing adjacent to ivy gourd.

Adult *M. oedipus* may be recognized by the clear hindwing typical of sesiids and by heavy scales on the hind legs which are characteristic of the genus *Melittia*. Wing length is 10–15 mm. A wide, white, dorsal band on the abdomen and red scales on the forewing distinguish this species from other *Melittia*. Adults as well as eggs and pupal exuviae are pictured in Eichlin (1995). The larvae are cream-colored with a brown head capsule and very short prolegs. When mature, they reach an average length of 22 mm (range of 17–27 mm). Eggs are dark brown, hemispherical in shape and are approximately 1 mm long.

## Discussion

This study found that no plant species other than ivy gourd was an acceptable host to ovipositing females of *M. oedipus*. With the exception of cucumber, only minimal larval feeding occurred on a small number of tested plants, and all of these were in the family Cucurbitaceae. This is consistent with previously mentioned references, which state that host plants of the genus *Melittia* are restricted to the family Cucurbitaceae.

Cucumber was the only non-target species on which a few larvae developed to the adult stage. However, the adults raised on cucumber emerged an average of two weeks later and were smaller than those produced on ivy gourd. None of them mated or laid eggs when placed on new cucumber plants.

In the four and a half years since *M. oedipus* was released on Oahu, there have been no reports by farmers or home gardeners to University of Hawaii extension agents or to the HDOA of attack on cucumber, or any other non-target species, despite widespread populations of the moth near small farms in Hawaii, nor have checks of cucumber and of endemic *Sicyos pachycarpus* shown any evidence of larval feeding damage. In addition to the fact that Burkhart did not find *M. oedipus* larvae in the stems of any cucurbit other than ivy gourd in Kenya (R. Burkhart, pers. comm.), inquiries to entomologists at the International Institute of Biological Control in Kenya found them to be unaware of this species. It is unlikely *M. oedipus* would be unknown to them if it were a pest of commonly grown cucurbit crops in Kenya.

From August 1996 to August 1999, approximately 21,600 adults and 16,000 larvae of *M. oedipus* were released on Oahu, and the moth is now well established throughout the island. In areas where large numbers were initially released, there has been a substantial reduction in the density of large vines. The tendency of females to lay eggs where other larvae are already present often weakens even thick vines and causes them to break. Damaged vines are attacked and further weakened by pathogens and other insects, such as the banana moth, *Opogona sacchari* (Bojer), which are attracted to the decaying vines. It took approximately three years of moderate to high *M. oedipus* populations to destroy ivy gourd vines at sites such as Punchbowl, where initial releases were made. It is hoped that in several years, the moth will be able to reduce the amount of ivy gourd throughout Oahu to a non-nuisance level.

To date, no parasitoids have been found in more than 400 field-collected larvae and pupae of *M. oedipus*. However, in 2001, a few male eupelmids, *Eupelmus* sp., were reared from field-collected eggs. There has also been evidence of ant predation on neonate larvae. The most damaging natural enemy has been rats, which tear open ivy gourd vines to feed on *M. oedipus* larvae. Rat predation impeded establishment at initial release sites when large numbers of larvae were placed in close proximity in order to increase the probability of adults finding mates while populations were small. Once the problem was discovered, adults instead of larvae were used in field releases, since female moths disperse eggs over a wider area and rats find a smaller percentage of the immatures. This proved to be much more effective despite the added effort required to raise sufficient numbers of the slow-growing larvae in the laboratory. Further data are being collected on ivy gourd and *M. oedipus* populations on Oahu, to be reported in a future publication (T. Culliney and M. Ramadan, pers. comm.).

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