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FIELD BIOLOGY OF *PYRAUSTA PERELEGANS* (LEPIDOPTERA: CRAMBIDAE): A FLOWER BUD-FEEDER ON *PASSIFLORA MOLLISSIMA*, AN INVASIVE VINE IN HAWAIIAN FORESTS

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Abstract - This study is a continuation of efforts to monitor a population of the biological control agent, *Pyrausta perelegans* Hampson (Lepidoptera: Crambidae), which specializes on the flower buds of the forest invasive vine *Passiflora mollissima* (H.B.K.) Bailey. Post-establishment studies were conducted to evaluate the effect of *P. perelegans* and factors affecting its colonization potential shortly after its establishment in the Olaa rain forest, Hawaii Volcanoes National Park (1800 m elevation), island of Hawaii. Moth population growth was monitored over a period of 16 months using a UV light trap. The moth appeared during months of 1992-1993, with a maximum population build-up during May (0.67 moth/night) and October (0.6 moth/night) of 1992. In March and May of 1993 the moth population peaked at an average of 0.4 moth/night. Mean moth catch per night during the two years was not significantly different. Overall mean percentage of vines infested with eggs of *P. perelegans* was 5.5% with a mean of 4.7 eggs per vine. Most of the eggs (75%) were deposited on the underside of young leaves with midrib lengths ranging from 2.5 to 6.5 cm. The overall percentage of egg parasitism by *Trichogramma chilonis* Ishii was 9.2%. Mean larval infestations were 7.5%, 2.0%, and 0.4% in small to medium buds (<1 - 6 cm), large buds (7 - 11 cm), and opened flowers (11 ->15 cm), respectively. Infestation was significantly higher in small to medium buds than large buds or opened flowers. No larval parasitism was observed in Olaa rain forest during this study. However, parasitoids recovered from other local Lepidoptera developed successfully in *P. perelegans* larvae in the laboratory. Laboratory and field observations on feeding behavior and establishment status in other areas on the Hawaiian islands are also reported.

Key words: *Passiflora mollissima*; *Pyrausta perelegans*; classical biological control; forest weed; insect colonization; Hawaii.

INTRODUCTION

Passiflora mollissima (H.B.K.) Bailey (Passifloraceae) is a perennial vine native to the higher elevations (1,830-3,660 m) of the Andes Mountains of South America, where it is cultivated for its colorful flowers and edible fruit (Figures 1- 2) (Schöniger, 1969). The vine, known locally as banana poka, was introduced to Hawaii as an ornamental plant in the early 20th century, and soon escaped cultivation (LaRosa, 1984). Under conditions favorable for reproduction and development at higher elevations (≥ 1,800 m), and without the complex of its natural enemies, this weed has spread unchecked (Warshauer *et al.,* 1983). As of 1986, it occupied 520 km^2 on three of the Hawaiian Islands (Kauai, Maui, and Hawaii) (LaRosa, 1992).

Passiflora mollissima vines often form continuous, dense stands in areas of sparse canopy cover and high feral pig (*Sus scrofa* L.) activity, causing a severe effect on native vegetation (Warshauer *et al.,* 1983). It has been identified as the most serious problem among native stands of koa *(Acacia koa* Gray) smothering seedlings and masking >8 m tall trees (Figure 1). Degeneration and loss of habitat for native Hawaiian flora were the impetus for controlling this spreading weed (LaRosa, 1992; Markin *et al.*, 1992). The vine spreads slowly, 0.6 to 1.3 km^2 per year, in Hawaiian rain forests (Warshauer *et al.,* 1983). Classical biological control, involving the introduction, testing, and establishment of potential natural enemies of the vine, was selected as the management method of choice, and is being conducted as a joint project of the Hawaii Department of Land and Natural Resources, University of Hawaii at Manoa, U. S. National Park Service, and U.S.D.A Forest Service.

Two insects from the Andes Mountains were cleared for field release in Hawaii. In 1988, more than 10,000 larvae of a Colombian moth, *Cyanotricha necyria* (Felder & Rogenhofer) (Lepidoptera: Notodontidae), which feeds on *P. mollissima* leaves, were released, but failed to become established (Markin and Nagata,1989). A second lepidopteran, *Pyrausta perelegans* Hampson [Family: Crambidae, following Minet's division of the Pyralidae into Crambidae, which includes the subfamily Pyraustinae (Minet, 1982)] (Figures 3-7) was released in February 1991 at the Olaa rain forest (Hawaii Volcanoes National Park, Olaa, Hawaii island) where *P. mollissima* buds and flowers are abundant and accessible for sampling during the whole year (Figure 1-2). While searching for specialized natural enemies in South America, Pemberton (1989) identified this crambid as a potential biocontrol agent for Hawaii. It is found in Colombia, Ecuador, Venezuela, and Peru. Larvae are bud feeders (Figure 6), and fruit and tips of shoots are sometimes infested by early instars (Pemberton, 1989). Large numbers of flower buds are destroyed and fruit yields drastically reduced by feeding larvae (Rojas de Hernandez and Chacon de-Ulloa,1982; Causton *et al.,* 2000). *Pyrausta perelegans* is not known to survive and reproduce on any native Hawaiian plants or other species of *Passiflora* now found in Hawaii, including the commercially grown passion flower (*Passiflora edulis* Sims), (Markin and Nagata 2000).

On the island of Hawaii, 1,126 *P. perelegans* eggs and larvae were released from February to May of 1991 in the Olaa forest. *Pyrausta perelegans* eggs and larvae were also released in small numbers in Laupahoehoe Forest Reserve (445 eggs, July 1991) and Hualalai, Honuaula Forest Reserve (140 larvae, April and July 1992) (Figure 8). The moth was reportedly breeding naturally three months after its original release in Olaa forest (Campbell *et al.,*1995). However, establishment was not noted in other release areas, e.g., Laupahoehoe, Puuwaawaa, Kohala, Hualalai. Establishment was also not successful on the Island of Kauai (Kokee Forest Reserve) after release of 718 larvae and 18 pupae.

We report in this study on the field biology and progress of *P. perelegans* establishment following its release in the Olaa forest. Moth population growth, egg abundance, larval infestation levels, and percent parasitism were determined, and oviposition behavior noted following its release.

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Fig. 1-2. *Passiflora mollissima*, introduced into Hawaii by the horticultural industry as an ornamental, soon escaped from cultivation to higher elevation rain forests: 1. Typical scene in native forest where *P. mollissima* has been established, choking out 520 km^2 of native rain forest. 2. Flower bud and an open flower. The pink hanging flowers attract birds for nectar. Abundance of flowers producing banana shaped fruit (>15 green fruit in figure 1, rectangled) which turn yellow when fully ripe.

MATERIALS AND METHODS

Adult trapping and larval feeding activity. Experiments were conducted at the Volcano Experimental Station of the University of Hawaii located at the Olaa forest, 1800 m elevation and Olaa Tract, Hawaii Volcanoes National Park, Hawaii Island, where *P. mollissima* has recently invaded. Abundance of *P. mollissima* vines was generally low (5000 plants per hectare, LaRosa, 1992), in comparison to other infested areas.

A simple light trap ("Universal black-light trap," Bio-Quip Products, Gardena, CA) was placed ≈3 m above ground in the insect release area of Olaa forest and was operated from April 1992 to July 1993. Because of electric power outages, the trap was not operational on all nights. When operable, it was run from sunset to sunrise. The light source was a 10-watt fluorescent UV tube, powered by 120-v AC, 60 Hz electric current. A 19-liter polypropylene bucket contained the trapped insects and permitted minimal escape. No killing agents were used in the trap to avoid effect on rare endemic moths and to retrieve live healthy *P. perelegans* for laboratory rearing and redistribution to other release sites. On cold mornings, some *P. perelegans* were usually found inactive on the edges of trap baffles or on the outside of the trap bucket, these were also counted. The trap was checked daily, and *P. perelegans* were sexed and counted. Females are separated from males by the pink wing margins and their abdominal morphology (e.g., genitalia and secondary sex characters in males) (Figures 3 and 4). Some of the trapped females were dissected, and the number of their ovarian eggs was recorded. Females were considered to have mated if they produced fertile eggs in the laboratory. Mean catches per night of *P. perelegans* during 1992 and 1993 were compared by *t*-test (SAS Institute, 1992).

During the months of December 1992 and February 1993, a UV light trap was operated nightly in upper Laupahoehoe Ohia-Koa Forest Reserve (elevation 2000 m) using a 12-v DC current car battery and timer. The Laupahoehoe Forest Reserve is on the eastern slopes of Mauna Kea mountain, Hawaii island, where *P. mollissima* infests approximately 40,469 hectares (Figure 8) (Warshauer *et al.,* 1983).

In the Hawaii Volcanoes National Park Quarantine Facility, insects were reared at ambient temperature, 14.7-17.3°C at 1200 m elevation. Climatological data during the study period were summarized from the Hawaii Volcanoes National Park station (Climatological Data Annual Summary, Hawaii and Pacific. 1992, 1993), the station closest to the trap.

Field and laboratory observations were recorded on larval feeding behavior, by checking feeding on different sizes of buds, flowers, and other parts of the plants.

Egg abundance and parasitism. Eggs of *P. perelegans* are circular, flattened in shape with irregular outlines and usually deposited on the underside of leaves (Figure 5). The vines of *P. mollissima*, from Olaa Tract (N 19° 26`, W 155° 16`) and nearby areas where initial release took place, were collected at least once a week starting from August 1992 until May 1993. Vines (25-50 per wk) were collected randomly from canopies less than three meters high. Total vines containing eggs and number of eggs and their position on the vine were recorded. Leaf sizes containing the eggs were represented by measurements of the midrib length (cm).

Viable eggs (not collapsed nor empty chorions) were placed in gelatin capsules to determine rates of parasitism. Eggs that had turned black or chorions with emergence holes were an indication of parasitism by egg parasitoids. Eclosed *Trichogramma* spp. were identified using keys by Oatman *et al.* (1982). Voucher specimens were deposited in the insect collection of the Hawaii Department of Agriculture.

Vine infestation by larvae. Mature larvae of *P. perelegans* (Figure 6) were collected from the field and reared individually in petri dishes provided with fresh flower buds to determine rates of parasitism. To study the infestation rates in relation to bud size, samples of flower buds (small: <1-2.5 cm long; medium: 2.5-6.0 cm long; closed blooms: 7-11 cm long; and opened flowers: 11->15 cm long) (Figure 2) were collected randomly in March 1993 when a high larval population was present. Lengths of buds and flowers were measured, and percentages of larval infestation were calculated as the number of infested buds divided by the total buds in the sample.

Status of establishment in other release sites on the Island of Hawaii. Other sites (Laupahoehoe [N 19° 55`, W 155° 20`]; Hualalai [N 19° 41`, W 155° 52`]; Puuwaawaa [N19° 44`, W 155°

52`]) where *P. perelegans* had been released in 1991 were visited periodically to determine establishment. Each survey involved leaf checking, bud dissections, and light trapping to detect the presence of eggs, larvae, or adults of *P. perelegans*, respectively. Samples of immature stages were held in the laboratory for possible parasitoid emergence. Further, parasitoids searching on *P. mollissima* and those emerging from the most common other Lepidoptera feeding on the plant (Mexican leaf-roller, *Amorbia emigratella* Busck [Tortricidae] and *Agrotis* spp. [Noctuidae]) were collected and maintained in the laboratory to determine their response to, and suitability for development in, *P. perelegans*.

TABLE 1. Comparison of light trap catches of *Pyrausta perelegans* during 1992 and 1993 in the Olaa rain forest, Volcano, Hawaii.

Date[a]	Nights trap operated per month (mean ± SEM)	Mean (±SEM) catch per month ♂♂	♀♀	Total	%♀♀	Catch per night (mean ± SEM)
Apr. - Dec. 1992	26.9 ± 2.7	4.8 ± 1.9	3.6 ± 1.2	8.3 ± 2.3	53.4 ± 10.4	0.32 ± 0.1
Jan. - Jul. 1993	19.7 ± 2.8	2.6 ± 0.6	2.9 ± 0.9	5.4 ± 1.4	41.2 ± 11.1	0.28 ± 0.1
t	1.82	1.10	0.64	0.79	1.01	0.36
P	0.09	0.30	0.66	0.44	0.33	0.73
Overall	23.8 ± 2.1	3.8 ± 1.1	3.3 ± 0.7	7.1 ± 1.4	48.1 ± 7.5	0.3 ± 0.1

[a] No significant differences were found between catch values during comparable months (April to July of the two years (*t*-test, P>0.05).

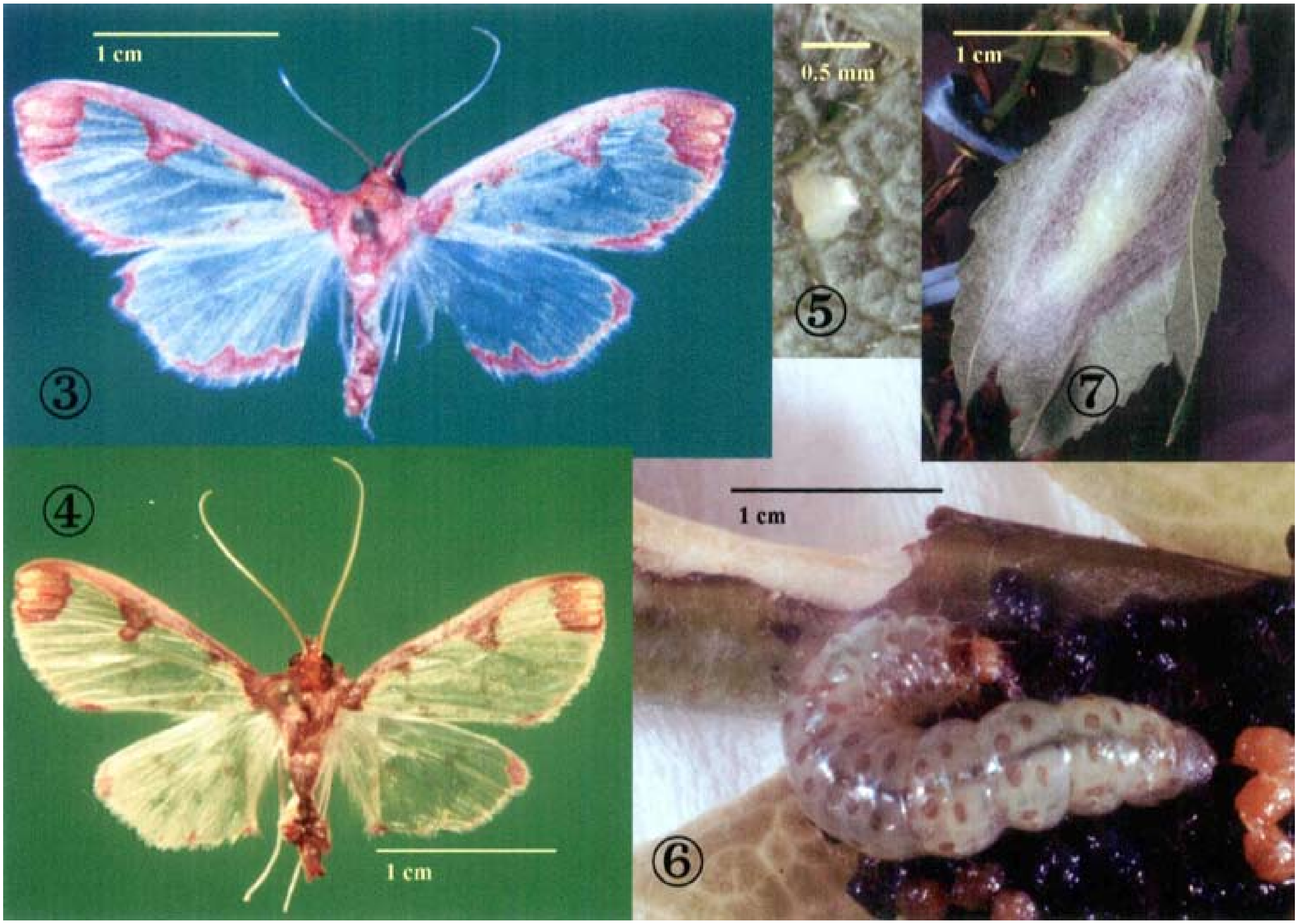


Fig. 3-7. Adults (pinned specimens lacking some wing scales) and immature stages of *Pyrausta perelegans*: 3. Female, 1.3-cm long with a 3.8-cm wing span. Forewings are white with light brown margins on the leading edges and a pink band along the trailing edge. 4. Male, slightly smaller than female with a 3.2-cm wing span. Male coloration is similar to the female's except for the absence of a pink band on the hind margins of wings. 5. Circular egg with irregular outline laid singly on an underside leaf surface of *P. mollissima*. 6. A typical crambid mature larva (out of an infested closed bud) consumes inner contents of buds and flowers halting future fruit production. The larva feeds on one side closer to calyx while frass accumulates at other end of bud. 7. Larva chooses a protected area between adjacent leaves and within a folded leaf and spins thin-walled, net-like cocoon. The pupa is a typical crambid, 1.3-cm long.

TABLE 2. Egg abundance and parasitism of *Pyrausta perelegans* on *Passiflora mollissima* one year following its release in the Olaa rain forest, Volacano, Hawaii.

Date	No. vine collection	Total vines examined	Total vines containing eggs	% Infested vines	Number eggs of *Pyrausta perelegans*				
					Hatching	Sound	Parasitized	Total	% Egg parasitism[a]
August, 1992	4	100	7	7.0	45	41	12	98	12.2
September	4	100	0	0	0	0	0	0	-
October	4	100	0	0	0	0	0	0	-
November	4	100	1	1.0	0	2	0	2	0
December	4	100	1	1.0	1	4	0	5	0
January 1993	4	100	5	5.0	0	14	2	16	12.5
February	7	225	36	16.0	30	176	19	225	8.4
March	6	275	25	9.1	10	35	16	61	26.2
April	4	125	13	10.4	0	35	6	41	14.6
May	4	125	7	5.6	0	14	0	14	0

[a] Calculated as (the number of eggs of *Pyrausta perelegans* containing *Trichogramma* spp. + eggs with parasitoid emergence holes divided by total number of eggs)X100

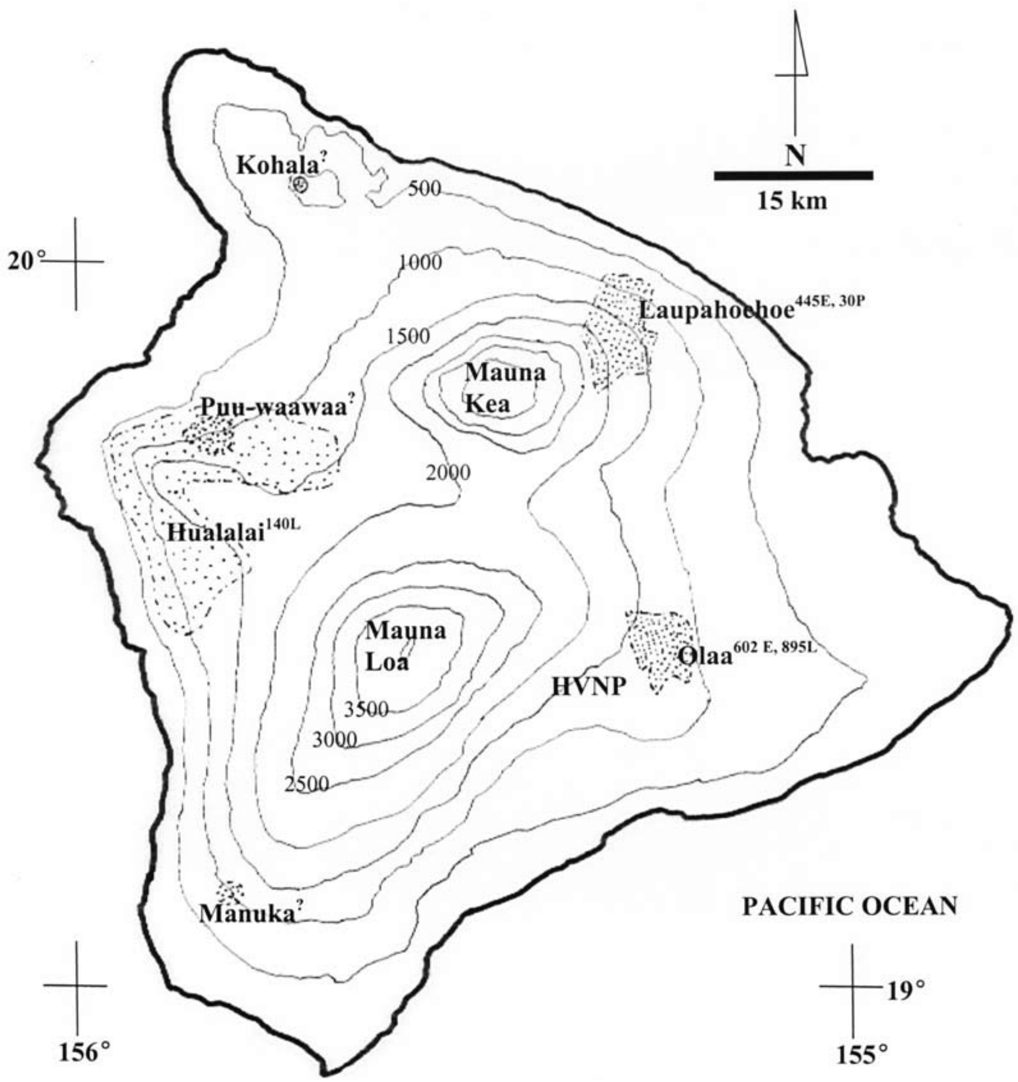


Fig. 8. Banana poka infestation, release sites and numbers of *Pyrausta perelegans* (in superscript, E=eggs, L=larvae,P=pupae, ?= no records) on the Island of Hawaii. Contour intervals every 500 meters. Dotted areas showing continuous (heavy dots) and sporadic (light dots) distribution of *Passiflora mollissima* on the island of Hawaii (after La Rosa 1992).

RESULTS AND DISCUSSION

Adult trapping and larval feeding behavior. Seasonal fluctuations in temperature and rainfall in Olaa forest are important regulating factors for Lepidoptera. However, there was a weak correlation between rain fall and trap catch per day in this study (r = - 0.38). Flight activity was not influenced by increasing or decreasing amounts of precipitation (F =1.66; df = 2, 13; P = 0.2275) (Figure 9). Other tropical Lepidoptera have shown similar erratic occurrences in rain forests of Belize and Costa Rica (Meerman 1999). Adult *P. perelegans* were trapped during all months of the two years with a maximum population build-up in May (0.67 moth/night, temperature of 17.6°C), September (0.45 moth/night, temperature of 19.1°C), and October (0.6 moth/night, temperature of 15.8°C) of 1992. Adults also appeared in moderate numbers during March and May 1993 (0.4 moth/night, temperature of 15.5°C). Analysis of light trap catch and relative build-up of the moth population was compared during 9 months of 1992 and 7 months of 1993 (Table 1). Moth catch per night between the two years were not significantly different (t = 0.3556, df = 14, p = 0.7274). Also, no significant differences were found between catch values during similar months (April to July) of the two years (t = 0.5222, df = 6, p = 0.6202).

Males and females were attracted equally to the trap. The overall mean percentage of females (48.1 ± 7.5%) was not significantly different from that of males (*t*-test, P >0.05). Those females attracted to the trap were mated and laid fertile eggs when brought to the laboratory (n = 32). Three females were dissected, and their ovaries contained a mean of 398 ± 33.5 mature and immature ovarian eggs. Being nocturnal, the moths were rarely seen during the day in the field, and in laboratory cages they were concealed under leaves.

The larva enters a flower bud through an opening usually cut close to the bud tip, and then seals it with silk. Larvae feed on flower parts (ovary, anther, gynophore, inner flower tube, and petals) (Figure 6). Usually, the larvae fasten the small buds (<3 cm long) to the peduncle or stem, before they enter, to avoid bud abortion during feeding or before they move to another bud. They defecate in a distal end of the bud, but feed close to the calyx tube. This feeding behavior may have some sanitary advantage or may allow larvae to evade parasitoids that locate their hosts using cues from frass. In the laboratory, second instar required 3-6 flower buds before they could complete development to the prepupal stage. Different sizes of bud-exiting holes were noticed in field-collected buds, supporting the hypothesis that larvae need more than one bud during larval development (five instars).

Pupae were not found inside the buds or on leaves of a low canopy, <3m high. In laboratory cages, mature larvae migrate to the upper corners for pupation, and may behave similarly in the field in folding leaves on the top of the canopy (Figure 7).

Larval feeding on plant foliage was rarely seen in Olaa, but occasionally early instars were found feeding between folded and adjacent leaves. Only on one occasion was a third instar *P. perelegans* found feeding on a *P. mollissima* leaf in the field. However, the vine fed upon had no buds, which may explain the atypical feeding behavior. In the laboratory, *P. perelegans* is commonly reared on leaves during first and second instars with some buds offered to later larval instars. However, adults of laboratory-reared *P. perelegans* using this method were smaller and their potential fecundity was lower than those collected from the field (based on wing measurements of males and females) (250 vs. >390 eggs).

Larval feeding on leaves and mining vine tips were seldom seen in Olaa forest. Only on one occasion where no buds were on the vine and the leaves contained many eggs did a vine tip harbor seven first instars. This feeding behavior was frequently seen in the laboratory because buds on *P. mollissima* bouquets abort quickly and may not stay more than five days on a cutting.

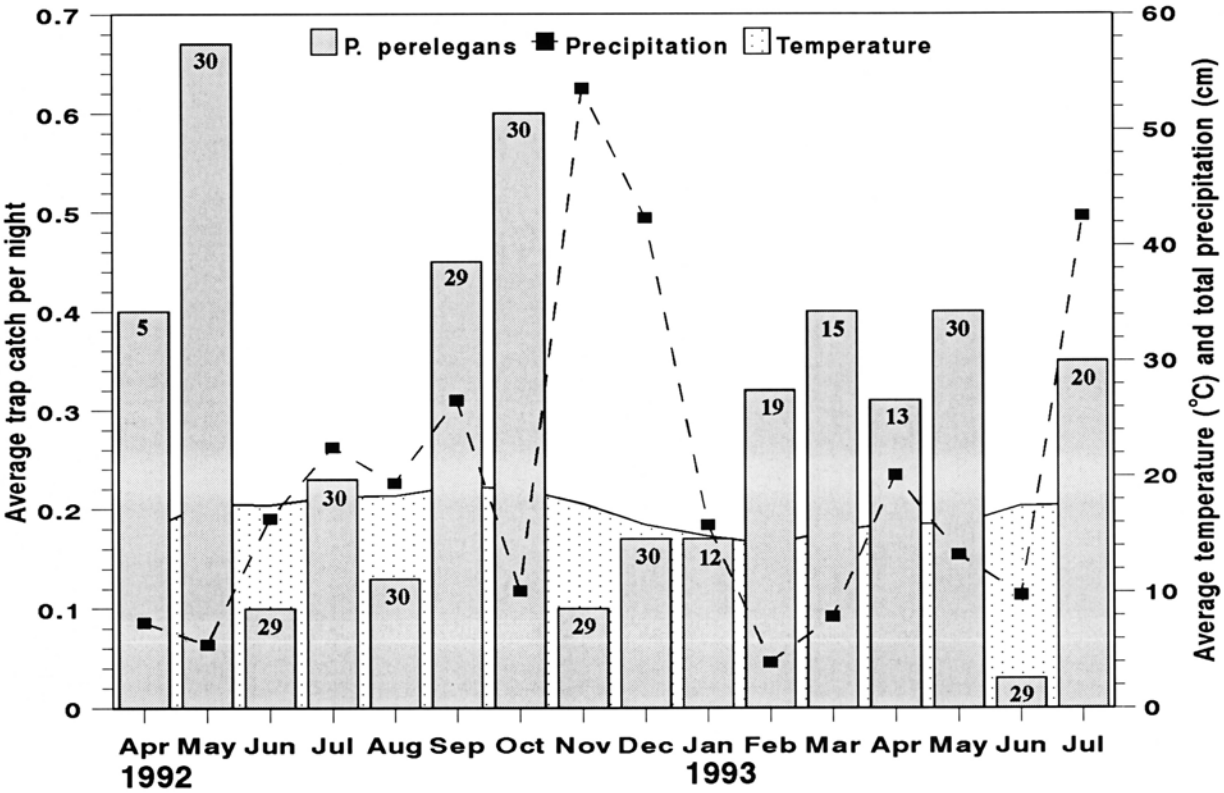
Although the common name of *P. perelegans* is “tip borer,” this feeding behavior was rarely seen in South American fields (Pemberton, 1989; Causton *et al*., 2000). However, during an exploratory trip to Columbia in December 1990, tip mining was common (Markin, personal observation). We postulate those *P. perelegans* population in South America to have two biotypes; one attacking the flower buds and another attacking the tips of green shoots or young fruit. However, observations on tip boring behavior in Hawaii seem to be a function of bud availability. Pemberton (1989) noticed more buds in Hawaii than in the Andes. Presumably, the high infestation in the Andes Mountains (Rojas de Hernandez and Chacon de-Ulloa, 1982) may force *P. perelegans* to lay more eggs on shoots containing fewer buds to sustain the larvae. Accordingly, the larvae may be obligated to attack the tender tissues on shoot tips or bore into small fruits that provide shelter and comparable nutrients if other food sources are not available.

Egg abundance and parasitism. In the laboratory, one female moth from the light trap was confined for four days in a cage with a *P. mollissima* shoot of nine leaves, and laid 145 eggs on both surfaces of leaves and 13 (8.2%) eggs on the stem. This equaled a mean production of 39.5 eggs per day. Higher percentages of eggs were laid on the lower surface (61.0 ± 13.6%) than upper surface (39.3 ± 13.9%), but differences were not significant (*t*-test, P = 0.284). However, this behavior was not observed in the field where eggs were commonly deposited on the leaf underside and occasionally on stems or bud bracts.

At the Olaa Tract, percentages of vines infested with *P. perelegans* eggs ranged from 1 to 7%, and 5 to 16% during the August-December 1992 (17.9 ± 0.6°C, rainfall = 304.0 ± 78.4 mm/mo) and January-May 1993 (15.2 ± 0.3°C, rainfall = 121.7 ± 28.5 mm/month) periods, respectively (Table 2). Overall mean (±SEM) percentage of infested vines was 5.5 ± 1.7%. Average numbers of eggs per infested vine were highest during August 1992 (18.3°C, rainfall = 193.8 mm) and February 1993 (14.1°C, rainfall = 39.4 mm), with an overall mean 4.7 ± 1.4 eggs (Figure 10). More than 75% of the eggs were deposited on leaves with midrib lengths ranging from 2.5 to 6.5 cm (Figure 11). These are the first four true leaves from the tip of the vine. Egg parasitism was highest in March 1993 (15.2°C, rainfall = 78.7 mm), and the overall mean percentage of egg parasitism was 9.2 ± 3.3% (Table 2).

Egg abundance in the field did not coincide with light trap catches of adult *P. perelegans*. Oviposition by *P. perelegans* appears to be influenced by vine height on the host canopy. Sampling vines on canopies less than 3 m in height may obscure the true structure of the egg population at Olaa. On several occasions, the vines on the top of the canopy contained more eggs than those close to ground level. Out of 50 shoots collected from ground level in Olaa (May 1993, 15.8°C, rainfall = 132.1 mm/month), only a single vine was infested (2% infested vines) with one egg on the third leaf (length

Fig. 9. Monthly average temperature (°C), total precipitation (cm), and average numbers of *Pyrausta perelegans* caught per night in black-light trap operated in the Olaa rain forest (Hawaii Volcanoes National Park, Island of Hawaii) from April 1992 to July 1993. Numbers inside bars represent nights trap operated/month.



of midrib = 3.5 cm). A sample of 25 shoots collected at the same location from vines, >2 meters above ground, with abundant buds, contained 13 eggs on five shoots (20% infested vines, 2.6 eggs per infested vine). However, further field observations on vertical distribution of eggs by this moth are needed to obtain accurate values for egg abundance in Olaa forest.

Campbell *et al*. (1995) recorded *Trichogramma chilonis* parasitizing the eggs of *P. perelegans* at Olaa forest with an overall mean parasitism of 56% (*n* = 167 eggs) during the first two generations of its establishment. This egg parasitoid is widespread and abundant in the Olaa forest (Oatman *et al*., 1982). Insect parasitism may limit population growth of this moth, but only egg parasitism by *T. chilonis* was encountered in this study. The parasitoid has a broad host range in the Olaa forest and is particularly abundant on egg clusters of *A. emigratella* (Ramadan, unpublished data). The abundance of *A. emigratella* and its eggs in the Olaa forest may act as an important reservoir for *T. chilonis,* and increase parasitism of *P. perelegans*. *Pyrausta perelegans* egg duration in Olaa is 11-14 days during the summer and winter seasons, respectively, which is an ample exposure time for parasitism by egg parasitoids. Rates of egg parasitism by *Trichogramma* species appear to increase with the increasing duration of exposure to hosts (Waage 1988). In the field, one or two *T. chilonis* adults may emerge from a single egg of *P. perelegans*.

Vine infestation by larvae. During early post-establishment periods, Campbell *et al*. (1995) recorded a maximum larval occupancy of 5.7% (six vines out of 105 vines containing infested buds). Even with tagged vines inoculated by laboratory-reared larvae of *P. perelegans*, the infestation was only 55% (Campbell *et al*., 1995). All *P. perelegans* instars hide in buds, and this may reduce the effect of the parasitoid complex (braconids and ichneumonids) and predators (carabids and nabids), which were found searching on *P. mollissima* and attacking exposed Lepidoptera larvae (Ramadan, personal observation). Among the parasitoids were *Gelis tenellus* (Say), an adventive ichneumonid that attacks a wide range of Lepidoptera at Olaa forest, and an unidentified tachinid fly, which emerged from *A. emigratella*. An adventive carabid beetle, *Laemostenus complanatus* (Dejean), is abundant in Olaa, feeding at night on late instars inside the buds. Many buds were found emptied of *P. perelegans* without the normal larval exit hole. The western yellowjacket, *Paravespula pensylvanica* (Saussure), and the Japanese white-eye bird, *Zosterops japonica japonica* Meyr, are active insect feeders particularly on lepidopterans, in the Olaa forest (Gambino and Loope 1992; Ramadan, personal observation). These are the most common insect predators at the Hawaii Volcanoes National Park; predacious ant species are not common at undisturbed rainforests of high elevation (N. Reimer, Hawaii Department of Agriculture, Division of Plant Industry, personal comunication).

Larval infestation in buds and flowers was monitored in March 1993 (15.2°C, rainfall = 78.7 mm) when larvae were abundant in the field after an egg population increase during February (Table 2). Larval infestation was 7.5 ± 2.0% (*n* = 913), 2.0 ± 1.5% (*n* = 108), and 0.4 ± 0.4% (*n* = 87) in small buds, large buds, and opened flowers, respectively. Infestations were significantly higher in small buds than in opened flowers and large buds (Tukey's HSD test, *F* = 6.62; df = 1, 15; *P* = 0.0087). More than 89% of larval infestation occurred in small (1.0-2.5 cm long) and medium (3-6 cm long) buds (Figure 12).

Forty-five *P. perelegans* larvae were collected from Olaa forest as third to fifth instars during February to April 1993 (15.1 ± 0.5 °C, and rainfall = 106.3 ± 48.6 mm/month) to determine parasitism. No larval parasitoids were collected from these larvae. Parasitoids were collected from other Lepidoptera larvae, particularly those of *A. emigratella,* found on *P. mollissima* or other nearby plants. In the laboratory, parasitoids of *A. emigratella* also developed on larvae of *P. perelegans*. However, it is possible that field larval populations of *P. perelegans* are not discovered by local parasitoids at this low population density. In Colombia, larvae of *P. perelegans* were parasitized by braconid wasps (Rojas de Hernandez and Chacon de-Ulloa, 1982), and parasitism of immature stages shipped to Hawaii was often 10-80%. Predators and parasitoids searching the *P. mollissima* leaves or recovered from *A. emigratella* were tested on *P. perelegans* in the laboratory. *Brachymeria obscurata* (Walker) (Hymenoptera: Chalcididae), is a pupal parasitoid usually seen searching the *P. mollissima* vines, and is known to use pupae of *A. emigratella* in Olaa rain forest. It developed successfully on pupae of *P. perelegans* in the laboratory. This is an introduced chalcid with a wide host range of pyralid species. Its development in *P. perelegans* pupae took 22 d under ambient laboratory temperatures. We do not know the effect of this parasitoid because pupae rarely were collected from the field.

Status of establishment in other release sites on the Island of Hawaii. Results of dissections of hundreds of small buds and flowers and surveys for eggs on foliage of *P. mollissima* from Laupahoehoe forest reserve (from July 1992 to February 1993, 23.1 ± 0.6°C, rainfall = 295.4 ± 66.8 mm/month) and Kona (Puuwaawaa site, December 1992 [23°C, rainfall = 388.6 mm/month]) revealed that *P. perelegans* is not established. A light trap operated in Laupahoehoe forest during December 1992 (22.4°C, rainfall = 307.8 mm) and February 1993 (20.5°C, rainfall = 47.7 mm) also failed to capture adult *P. perelegans*. The release method and the few cohorts released might well have been responsible for the non-establishment in Laupahoehoe where *P. perelegans* was released as eggs (445 eggs during July 1991), whereas in Olaa, most of the released stages were larvae.

New efforts to establish *P. perelegans* were made in 1993. *Pyrausta perelegans* collected from Olaa forest were reared in the laboratory, and 30 pupae were placed in paper cartons (20×15×5 cm, with exit holes and streaks of honey) suspended from *P. mollissima* vines in Laupahoehoe in July 1993 (22.7°C, rainfall = 53.8 mm). Two weeks later, *P. mollissima* shoots within a10-m radius around the release site were examined. Of 120 vines examined, only three (2.5%) had eggs of *P. perelegans* with a total of 16 eggs (2, 6, 8 eggs each; 10 eggs were hatching). This initial egg-laying activity by the emerged adults (5.3 eggs per vine) and egg hatching suggests that establishment in Laupohehoe is feasible with the release of quality-controlled pupae. Sampling in 1994 confirmed that *P. perelegans* is now well established at Laupahoehoe. Egg chorions were on the leaf on which they were laid, but the larvae migrated to new plants after hatching. Examination of egg chorions showed that eggs had hatched normally with no evidence of parasitism.

In May and September of 1994, *P. perelegans* infested 4% of the buds (*n* = 739 buds) in Laupahoehoe forest reserve. Also, it became established in Kula forest, Waiakoa ([N 20° 45`, W 156° 19`] Maui Island) during March and May 1994 with 2.4% bud infestation (*n* = 1409 buds). However, in Kokee State Park ([N 22° 07`, W 159° 39`] Kauai Island) there has been no evidence of establishment. On Hawaii island, bud infestation has increased slightly to 11.4% in the Olaa forest 1994 (*n* = 508 buds), but current effect on the

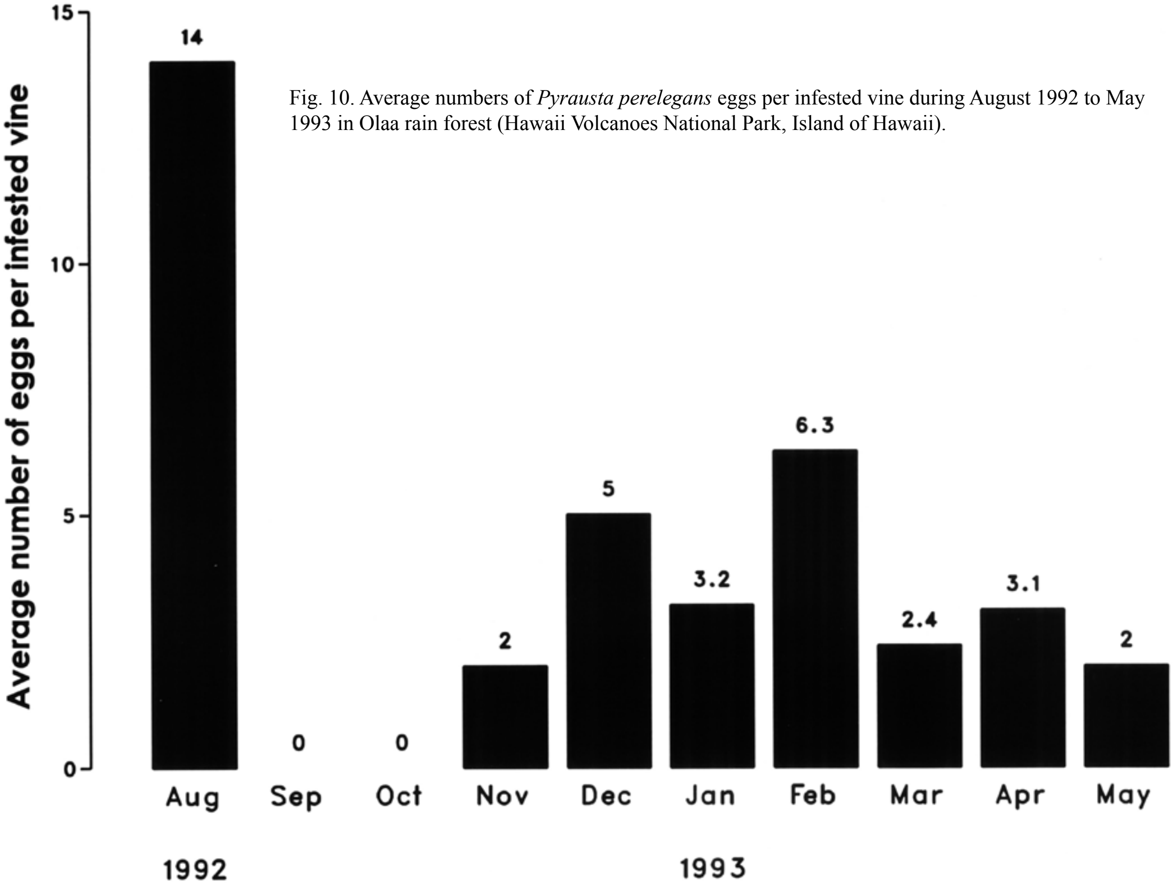


Fig. 10. Average numbers of *Pyrausta perelegans* eggs per infested vine during August 1992 to May 1993 in Olaa rain forest (Hawaii Volcanoes National Park, Island of Hawaii).

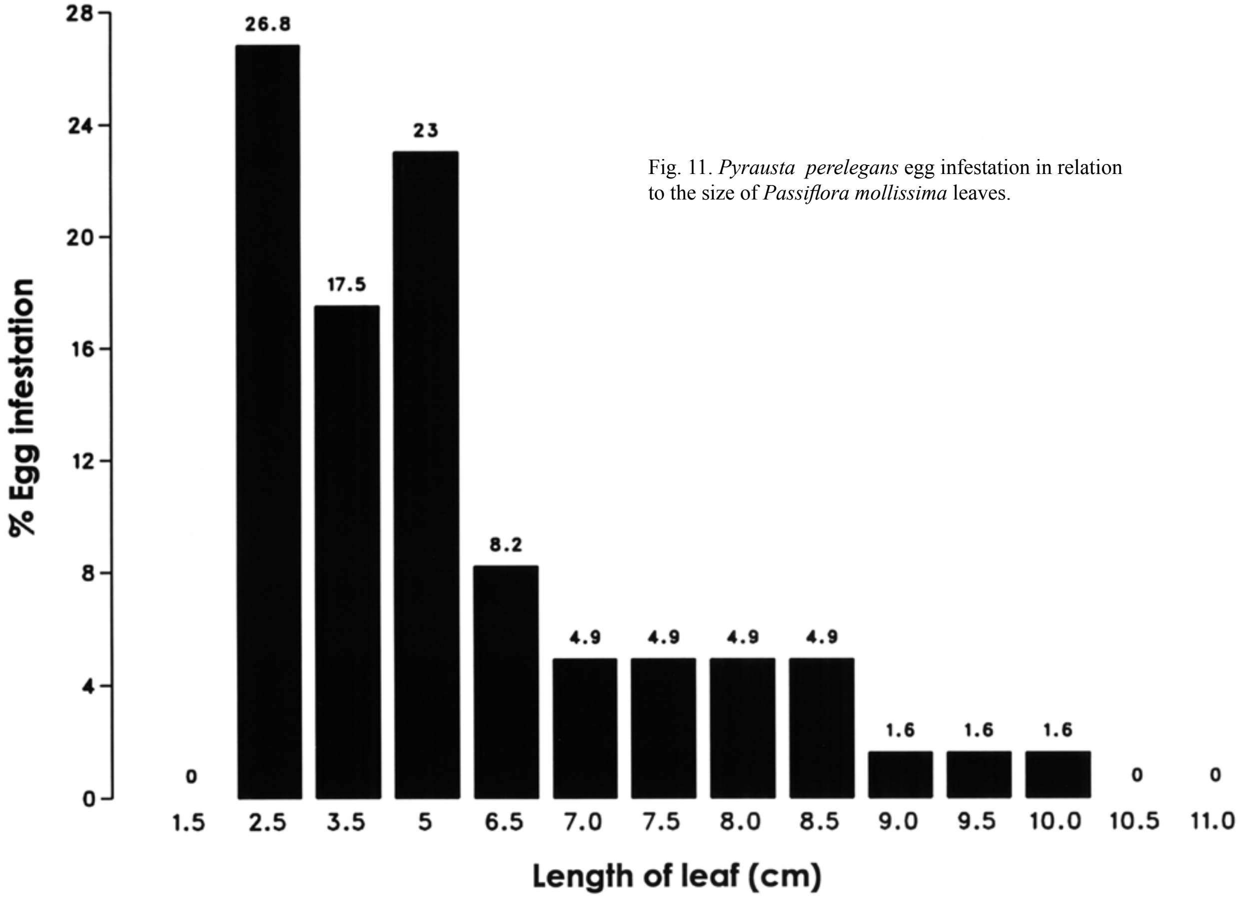


Fig. 11. *Pyrausta perelegans* egg infestation in relation to the size of *Passiflora mollissima* leaves.

vine appears to be low.

Destruction of flower buds will reduce fruit set and slow the further spread of this weed. It is hoped that *P. perelegans* will continue to spread into areas that are currently unoccupied. Based on results from trap catches and egg distribution, *P. perelegans* is reproducing at some sites, and its populations are enlarging slowly throughout the Olaa forest. Additionally, permanent establishment in Laupahoehoe forest and other new sites is possible. This study showed no evidence of effective biological control of *P. mollissima* (vine infestation range = 2-11%). The level of infestation needed for *P. mollissima* suppression is currently unknown. The moth is successfully established in Olaa from a very small release and there is a potential for further population build up.

Naturally occurring predators and parasitoids in Hawaii are thought to be reducing the effectiveness of several Lepidoptera species introduced for biocontrol of weeds (Markin *et al.* 1989; Campbell et al. 1993; Markin *et al.* 1996). However, low potentials of success due to parasitoid impact on *P. perelegans* in Olaa forest is not supported by our findings. This study shows insignificant parasitoid effect on *P. perelegans*. Here is another example of a biocontrol agent that does very well in its native lands and poorly in Hawaii (Markin *et al.* 1989; Campbell et al. 1993). Efforts to locate new agents to complement the effect of *P. perelegans* were initiated in 1990. A lepidopteran defoliator, *Josia flonia* (Druce) (Notodontidae), from Ecuador and a bud-feeding fly, *Zapriothrica salebrosa* Wheeler (Drosophilidae), from Colombia are being tested in quarantine for future field evaluations. These new biocontrol agents have been under petition for release since 1995 (R. Leen, Pacific Southwest Forest and Range Experimental Station, Forest Service, U.S. Department of Agriculture, personal communication). A bud-feeder, *Mycetophila* sp. (Diptera: Mycetophylidae), and a fruit-feeder, *Dasiops caustonae* Norrbom and McAlpine (Diptera: Lonchaeidae), from Venezuela are recommended as potential biocontrol agents in Hawaii (Causton *et al.,* 2000).

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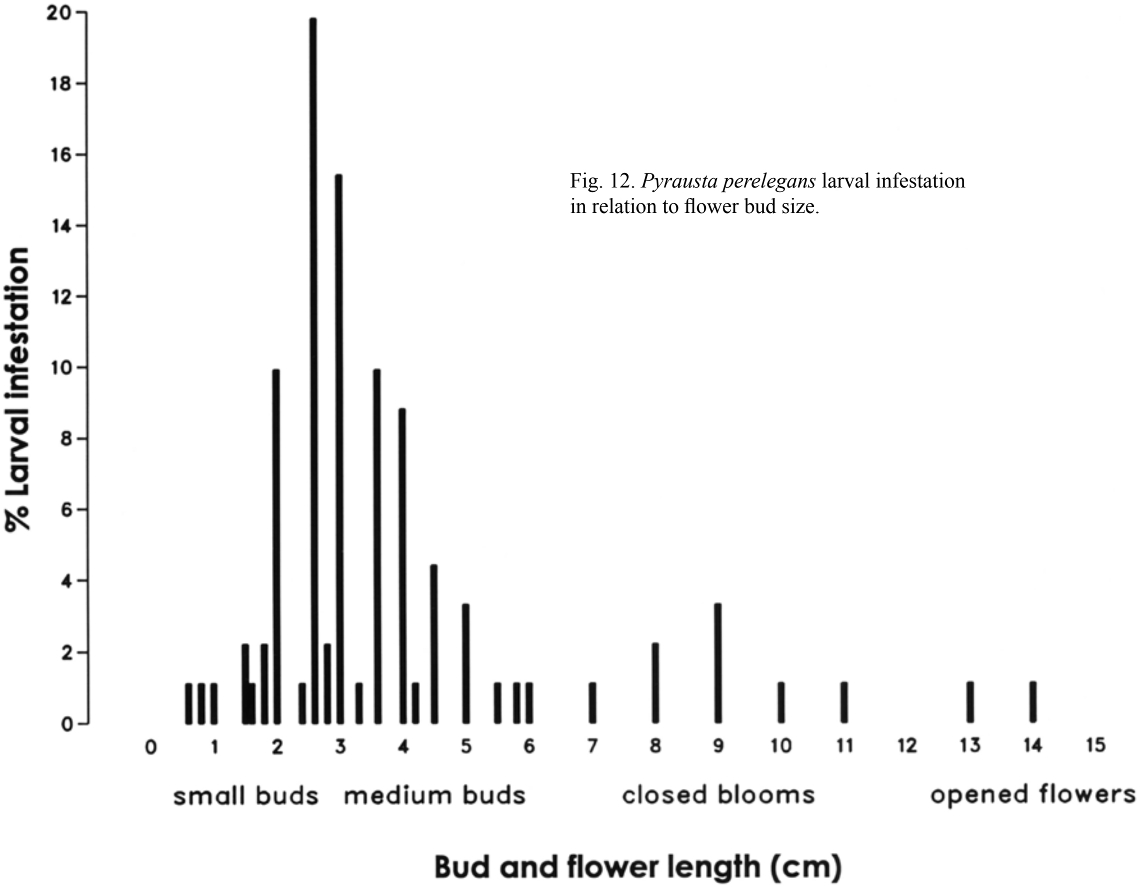

Fig. 12. *Pyrausta perelegans* larval infestation in relation to flower bud size.

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